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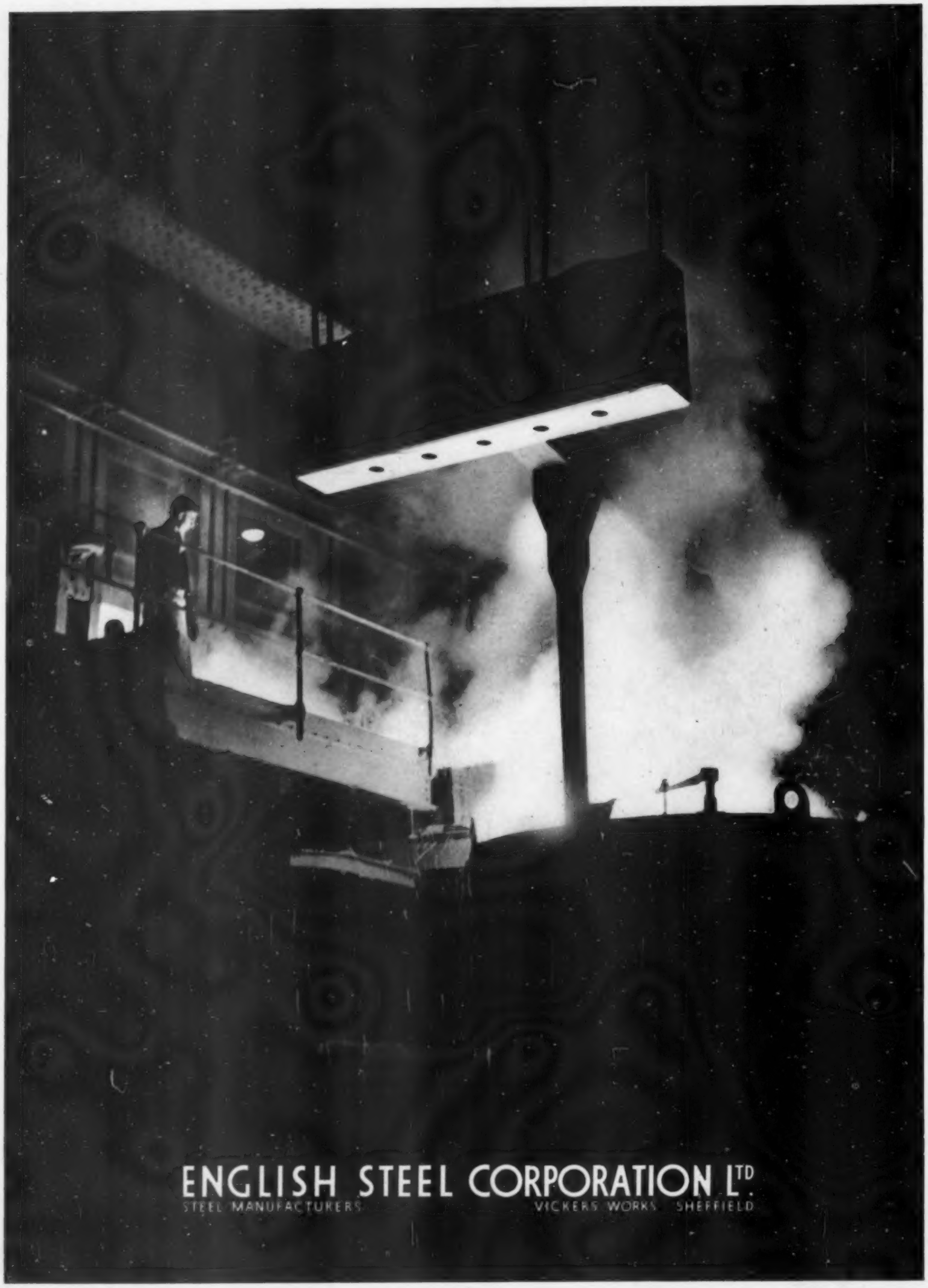
# METALLURGIA

## THE BRITISH JOURNAL OF METALS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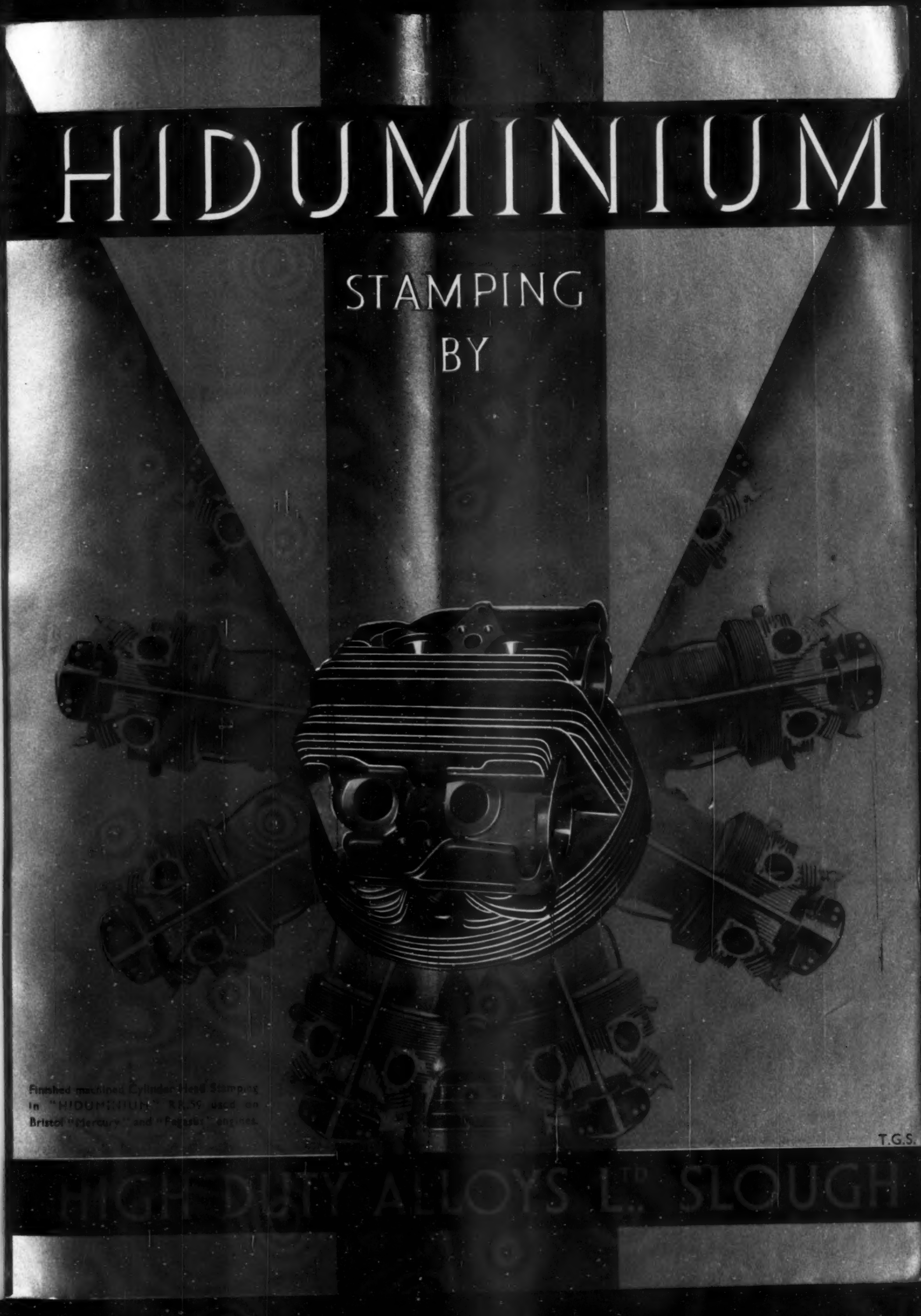
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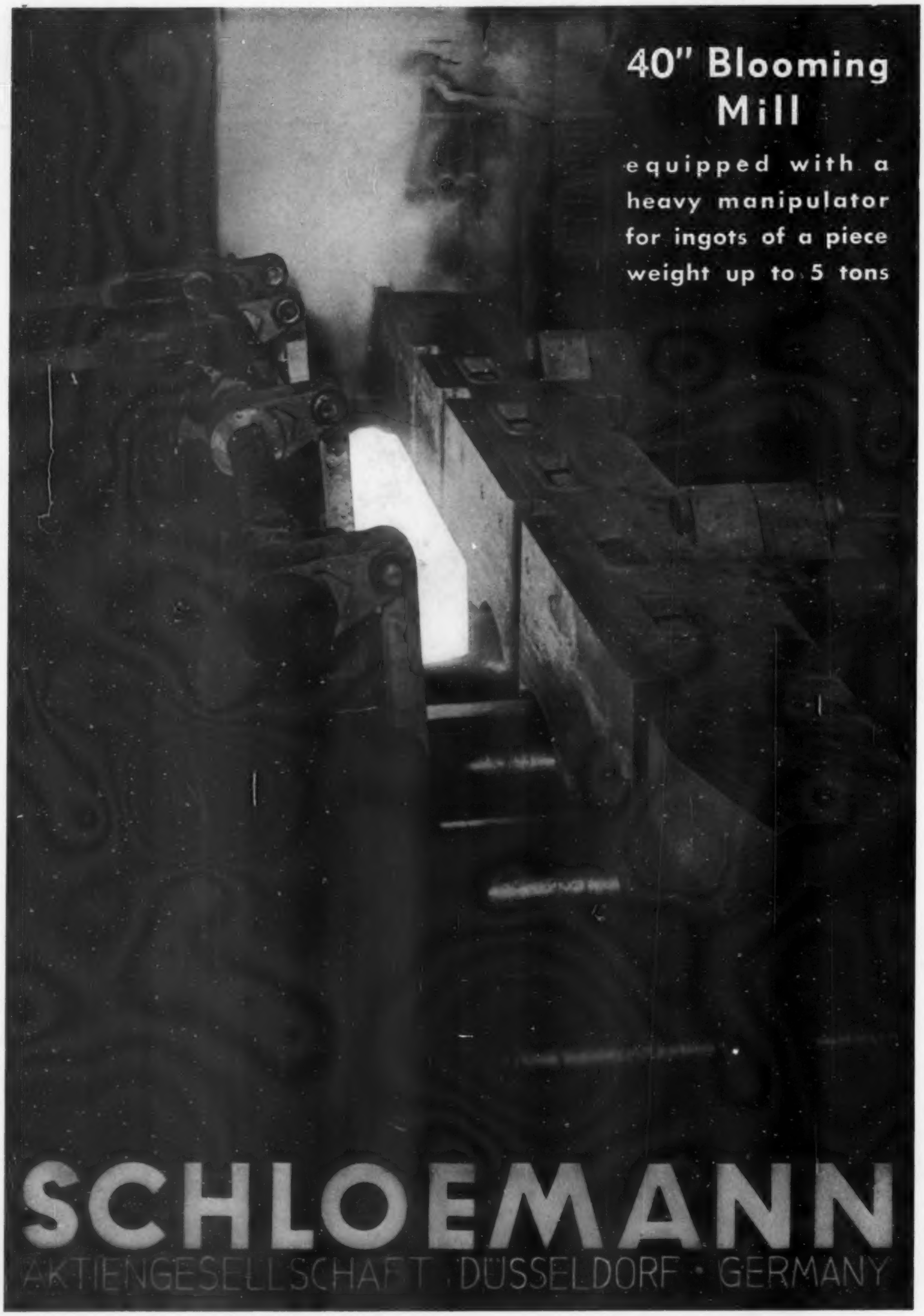

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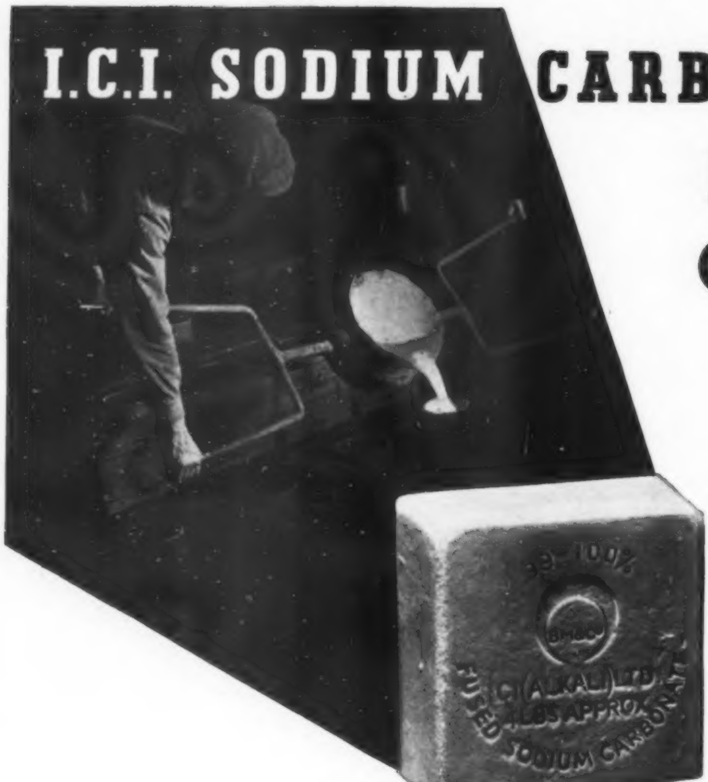




# Enamelling the Raleigh Cycle

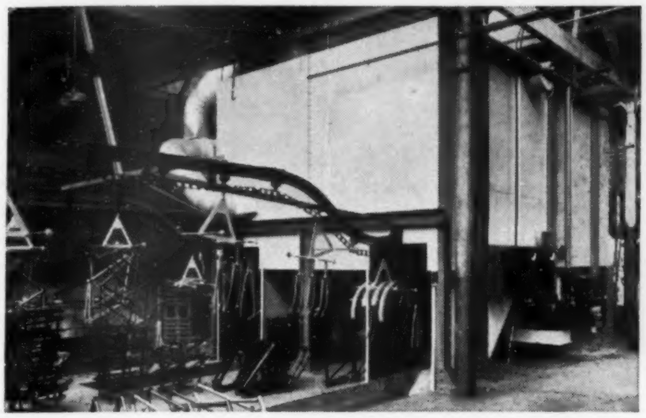
## Continuoūs production methods assisted by gas-fired ovens

THE Raleigh Cycle Company turns out 500,000 cycles a year. That output offers full scope for modern continuous production methods, and the Raleigh Company take full advantage of it.

One of the most important operations in the production of a cycle is that of enamelling. For this operation the Raleigh Company use seven gas-fired conveyor ovens. The use of town gas for enamelling ovens is spreading as it has many very important advantages.

The first advantage is its reliability. The gas supply never fails. It is always there in almost limitless quantities at a fixed price. The second advantage is that with a clean fuel like town gas a direct-fired air heater can be used in most cases where an indirect type would have to be used otherwise. Not only does this save fuel, but it simplifies and cheapens the maintenance of the oven, for air heater elements are made of expensive material and have to be replaced regularly.

No fuel can be so easily and accurately controlled as town gas. Oven temperatures can be accurately controlled with the simplest thermostats. The required oven conditions can be more readily obtained with town gas than with any other fuel. Another advantage is the saving in space and labour, for gas requires no storage or handling and calls for less cleaning work and supervision.



*Gas-fired conveyor enamelling oven for coloured finishes.*

### The Raleigh oven described

Cycle frames at the Raleigh works are enamelled in black and also various colours. These two groups are dealt with quite separately.

The standard black finished models are stoved in conveyor ovens measuring 56 ft. long by 9 ft. 6 in. wide by 5 ft. 6 in. high inside. One of these ovens is illustrated here.

*Gas-fired conveyor enamelling oven for black cycle parts.*

At the inlet end of each oven is a tiled dipping room. The parts undergo a three coat process and, as the average capacity of the plant is 10,000 complete cycles per week, some idea can be obtained of the immense number of parts treated.

Each oven is heated by an automatically controlled direct gas-fired air heater and is provided with a recirculating system.

Ingoing air and products of combustion are maintained at 500° F., providing a constant temperature of 460° F. in the oven. The chain conveyor passing through the oven is driven through a variable-speed gear by a 1 h.p. motor, giving conveyor speeds of 3½ ft. to 4½ ft. per min.

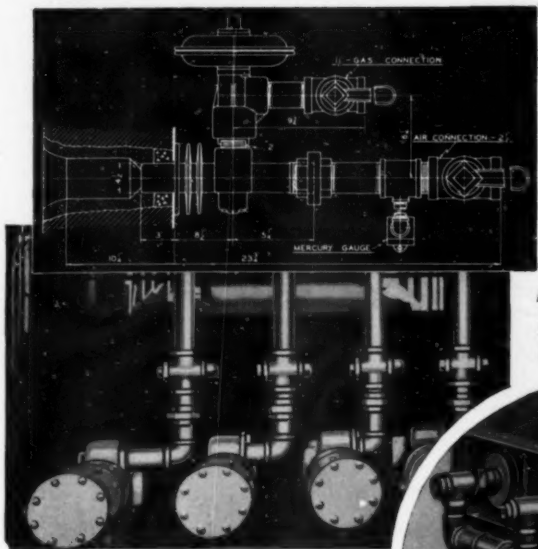
Colour finishes are dealt with in an oven measuring 25 ft. by 12 ft. by 9 ft., also illustrated here. In this oven the entry and exit of the conveyor chain are both at the same end, the chain making four passes up and down the oven chamber during one hour—the time of stoving.

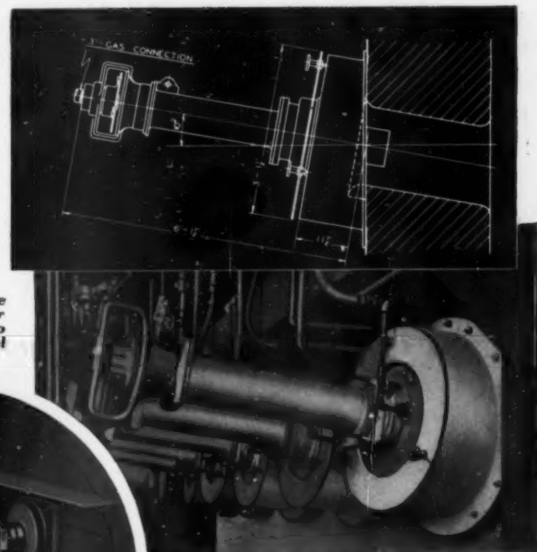
Small parts are dealt with in a similar oven. These number up to 650,000 a week.

### The question of cost

Estimating the comparative costs of fuels is no easy matter. It is entirely misleading to consider the fuel costs alone as the fuel influences so many other costs, all of which vary with circumstances. Taking all in all, however, it is now being widely realised that the use of town gas is an economy. Its saving in labour, space and furnace maintenance more than compensates for any extra cost of the fuel there might be.

All needing expert advice on gas equipment should write to The British Commercial Gas Association, Gas Industry House, 1, Grosvenor Place, London, S.W. 1, who will put the inquirer in touch with the body best equipped to assist him.





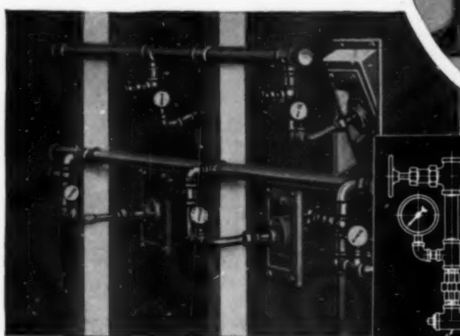
*High Pressure Inspirator manifolded to Three Tunnel Burners.*

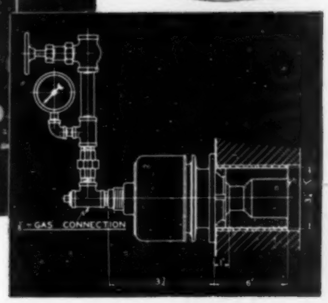
*Low Pressure Velocity Burners.*

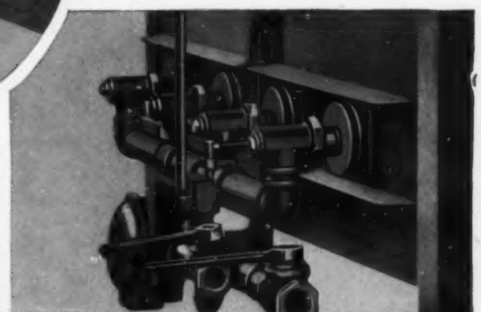
*Two-Stage High Pressure Velocity Burners.*

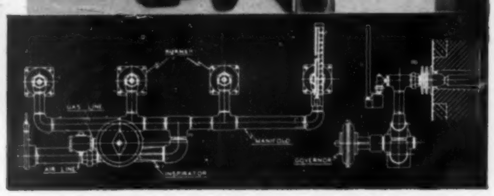
*SR Type Burner or reverberatory furnace.*

*Low Pressure Inspirator manifolded to Tunnel Burners.*









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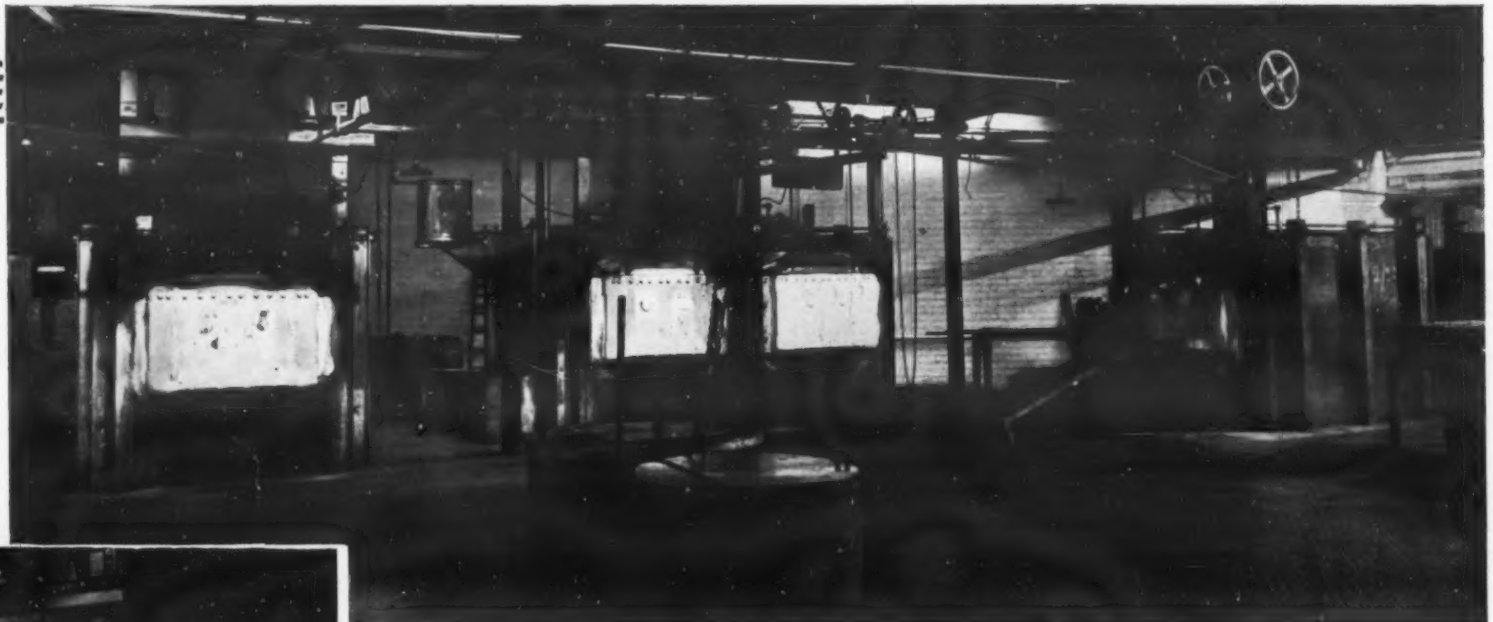

A battery of oil-fired carburising furnaces installed at the works of a large textile machinery manufacturing firm in Yorkshire.

The operation of charging a furnace

ACCURATE heat-treatment depends upon many factors, which vary with plant conditions, and to control these variable factors, long experience in furnace design is essential ; in every case, however, the economic test of the operation is proof, in the form of uniformly heat-treated products. We design to ensure the fulfilment of this economic test.

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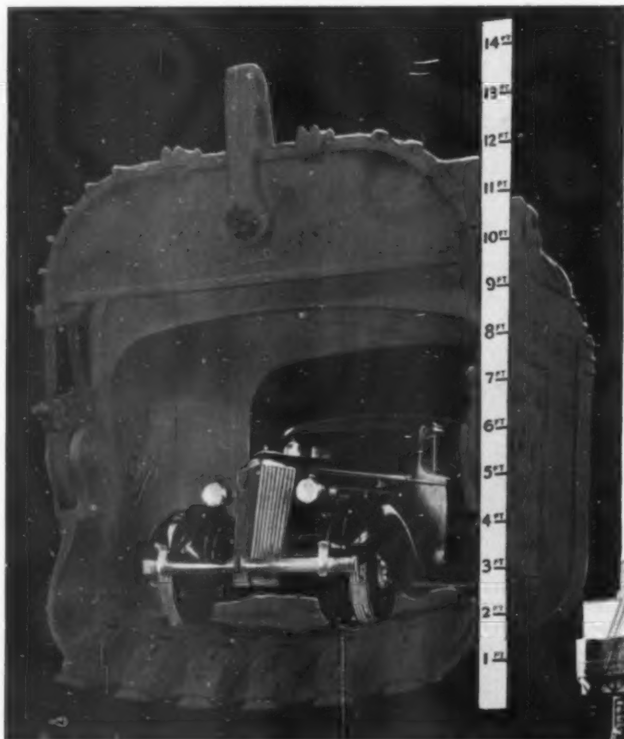

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*The British Journal of Metals*
(INCORPORATING THE METALLURGICAL ENGINEER.)



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METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER".

MAY, 1937. VOL. XVI. No. 91.

# Developing Special Steels

## The Brown-Firth Research Laboratories

*The essential work of these Laboratories lies in the consideration of scientific and technical problems arising in the operation and development of the processes and improvement, modification or utilisation of the products in which the associated companies are interested. A considerable proportion of the resources of these laboratories are devoted to assisting in the application of the various steels amongst the consuming industries.*

*The main buildings of the Laboratories.*

DURING a recent visit to the works of Messrs. Thomas Firth and John Brown Ltd., arranged in connection with the London Congress of the International Association for Testing Materials, when about 150 members participated, a desire to visit the laboratories was expressed by several of the visitors. So many interesting features are associated with these works, that it would be difficult to meet individual wishes in the short time at the disposal of as many visitors, but, through the courtesy of Dr. W. H. Hatfield, Director of the Brown-Firth Research Laboratories, we are permitted to give a brief outline of the work and equipment of these laboratories.

Situated practically in the centre of the many works of the special steel industry of Sheffield, the Brown-Firth Research Laboratories are conveniently placed for intimate contact between the research organisation and the plants with which it is its function to collaborate. The laboratories are naturally very close to the immediate industrial needs, but on the one hand fundamental scientific work is by no means neglected, and, on the other, support is accorded to the elucidation of any major scientific problems in which the steel industry as a whole is collaborating.

Despite the advances which have been made over the last decades, much work remains to be done in determining how best various engineering and other metallurgical problems can be solved, either by the present or by improved types of steel. Railway, shipbuilding, turbine, automobile, aero, textile, chemical, hydraulic and general engineering work all present problems calling for scientific treatment. Such matters as the technology of rust-, acid-, and heat-resisting steels, high-tensile steels, tool steels, spring steels, file steels, non-magnetic steels, magnet steels, steels of high coefficient of expansion, case-hardening steels, nitriding steels and special steels generally, demand scientific and technical consideration. Whilst primarily designed for the influence which they might bring to bear upon the processes and products of the associated companies, the laboratories are unhesitatingly placed at the disposal of manufacturing concerns which are utilizing the company's steels, for the purpose of assisting in the solution of consumers' own problems. The latter section of the work is extremely valuable, since it often assists the laboratories in determining the special direction which some of their investigations shall take.

The results of extensive investigations carried out in these laboratories have frequently been published, and are familiar to the engineering world. The laboratories may justly claim a share in the metallurgical developments of the last few decades. The first development of note followed from the discovery, in 1913, of the stainless cutlery steel containing approximately 0.30 % carbon and 13% chromium. It was immediately realised that there would be presented an enormous field of possible application for a stainless steel possessing a still wider range of resistance to corrosion, in conjunction with certain mechanical properties. The higher chromium steels were investigated, and nickel, in various percentages, was added. Thus was developed the "Staybrite" type of steel containing 18% of chromium and 8% of nickel. In response to a demand for a material for deep press work, the research laboratories were responsible for the introduction of a modification of "Staybrite" steel, namely, "Staybrite" D.D.Q., containing about 12% chromium and 12% nickel. The use of this steel, owing to its extreme ductility and malleability, has developed very rapidly. Subsequently, a number of further modifications have been developed to meet various special requirements. With the production of these special steels arose the necessity for the development of suitable processes for their manipulation by fabricators. This aspect was dealt with exhaustively by these laboratories and, as a result, a correct technique was developed for welding, hard and soft soldering, pickling, machining, pressing, spinning, and other manipulative processes. It was also during the course of these researches that the well-known copper-sulphate sulphuric acid solution was developed, which is now universaly accepted as a standard testing solution for determining that such steels have the desirable properties.

The laboratories have also played an important part in the development of the nitriding process of surface hardening steel and in its application to the many types of steel which can now be hardened in this way. In the world of

carbon steels and medium alloy steels, much attention has been paid to special products such as boiler drums for high temperatures and pressures, and to special steels for other associated equipment, such, for example, as bolts required to operate at steam temperatures. The treatment of tool steels and the development of high-speed steels are two other subjects upon which a considerable amount of work has been done. The demand for a steel having a high coefficient of thermal expansion comparable with that of aluminium has been met by the production of a special nickel-manganese-chromium steel, which was immediately covered by Air Ministry specification. This steel also finds valuable application as a high yield-point non-magnetic material for electrical work. The researches on the subject of heat-resistant steels, possessing both resistance to scale formation and strength at elevated temperatures, are also well known.

A research organisation must be very extensively equipped if it is to deal effectively with steels—particularly modified or new ones—in order to supply data for the complete examination of an alloy, which involves chemical analyses, metallographic examination, physical properties, mechanical properties at normal and elevated temperatures, mechanical properties at sub-normal temperatures, resistance to corrosion and chemical attack, resistance to scaling, response to heat-treatment, and additional data associated with the fabrication of the material. The organisation discussed in this article has steadily developed over the last thirty years, and has continually increased its resources for the adequate handling of problems in the industry. In the following notes reference is made to some of the laboratories in this organisation.

### Steel-making Laboratory

In studying the potentialities of new compositions in steel, it is of great advantage to be able quickly to produce small quantities of the compositions to be studied, although it must always be recognised that the final test of the properties of any particular type of steel must be carried out on such material as would be obtained on a production basis : that is to say produced in a medium or large-sized furnace as distinct from a small experimental unit. At the same time, much valuable pioneering work has been and is being done with material produced from small-scale equipment.

For many years the chief unit of the experimental plant attached to the laboratories has been an electric arc melting furnace of the tilting type, and the hearth employed can be adapted to the type of steel being produced. More precise control, both of temperature and of the physico-chemical reactions in the bath, is obtained in a special high-frequency induction furnace of 100 lb. capacity. This furnace enables steel to be melted under conditions approximating to commercial production. In addition, an electric resistance furnace of small capacity, fitted with auxiliary equipment for vacuum melting, has also been employed.

The heat-treatment laboratory is fitted with furnaces suitable for subjecting small objects and test-pieces of various kinds to experimental treatments. The equipment includes gas and electric muffles, furnaces, salt and oil tempering baths, each fitted with the necessary pyrometric equipment ; and oil and water quenching tanks.

The work of the pyrometric laboratory consists in part of the calibration and maintenance of the pyrometric equipment used throughout the works of the associated companies. Thermo-couples—mainly of the platinum/platinum-rhodium type, but also including base metal couples—are made up in the laboratory, calibrated, and kept in order by frequent checking and recalibration. All the indicators and recorders used throughout the works are also under the control of this department, and are repeatedly examined and recalibrated.

Optical and radiation pyrometers are used for temperatures exceeding 1,000° C. The maintenance of a complete set of disappearing filament instruments for routine determination of temperatures of molten steel in the works, as well as the periodic calibration of the polarising type pyrometers used in the many forge departments, are further duties of the pyrometric department. Other activities include the determination of heating and cooling curves, the construction of electrical furnaces for use in the various laboratories, actual observations of liquid steel temperatures during the tapping and casting of heats in the works and forging temperature observations.

### Mechanical Testing Laboratory

This laboratory is fully equipped with testing machnes designed to ascertain the mechanical properties of steels. These machines include Avery and Olsen universal tensile machines, Avery torsion, Wohler fatigue, Izod impact, Charpy impact, Brinel hardness testing, Erichsen sheet testing, Stanton repeated impact testing, Sankey bend, Saniter wear-testing and other machines. For the purpose of obtaining the stress-strain diagrams of tensile test specimens, various forms of standard extensometer are available, and others have been designed and constructed in the department itself. The laboratory has also designed and constructed a lateral extens meter so that determinations of Poisson's Ratio can be directly made.

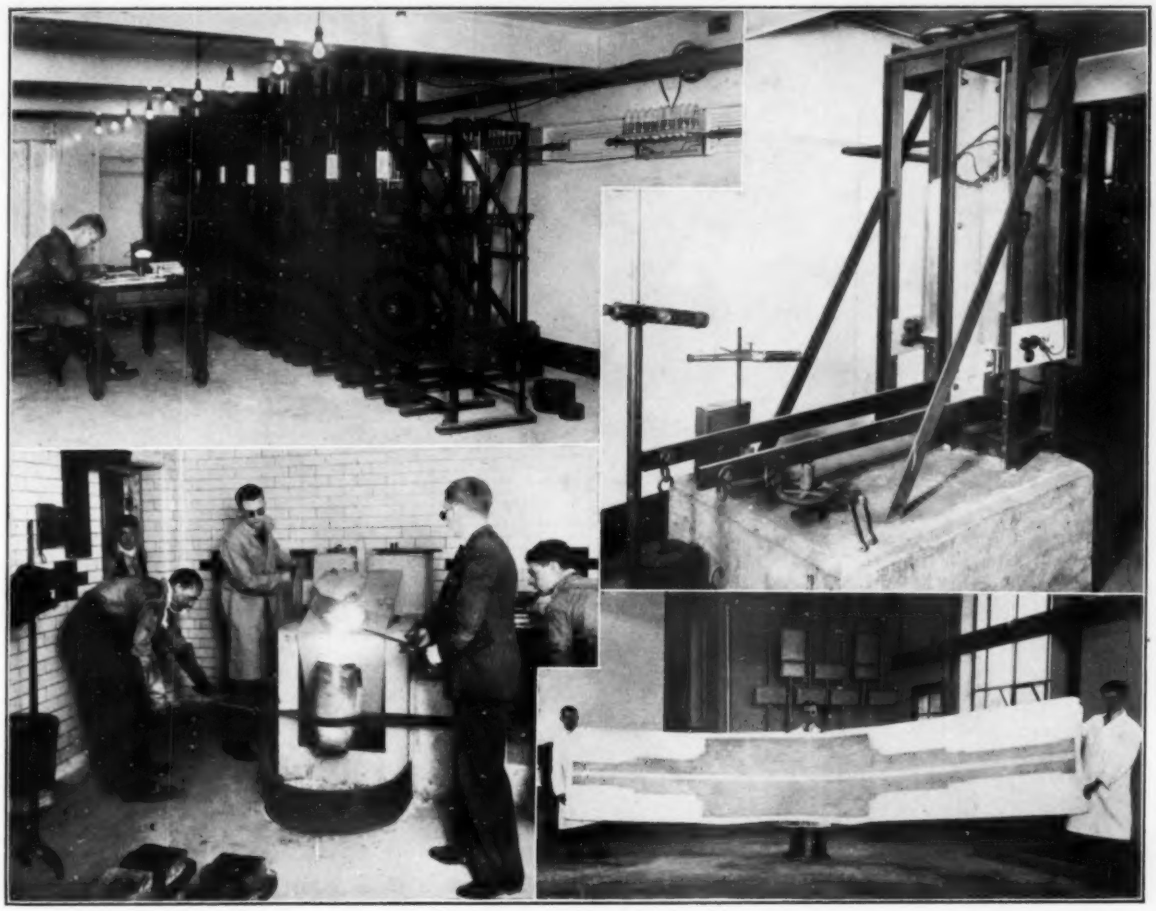
Apart from carrying out tests at ordinary temperature, the laboratory is equipped for carrying out tests at both elevated and sub-normal temperatures, and a wealth of data in these regions has been accumulated over a long period of years.

The laboratory for testing steels at elevated temperatures is situated in the basement of the building. The apparatus consists of a battery of machines for general purposes, the load being applied to the specimens under test by means of 20 : 1 levers supported on hardened knife edges. Each machine is provided with a suitable electrical resistance furnace, the temperature of which is controlled by means of iron wire filament resistance lamps. Changes in length of the specimens subjected to stress and temperature are determined by an external type of extensometer measuring to a limit of accuracy of one forty-thousandth of an inch. Temperature is constant to about 1° C., and is carefully adjusted to the initial temperature for each reading taken. The creep test which has been devised and adopted as standard by the Brown-Firth Laboratories is one lasting three days.

Special units of a more sensitive type have also been installed. These machines are capable of measuring rates of creep approaching one hundred-millionth of an inch per inch per hour. They are strongly constructed, and are embedded in a solid concrete base, load being applied by 20 : 1 levers. The furnaces are 24 in. in overall length, thus making provision for a specimen type, and are constructed in three sections, each controlled by its own rheostat.

Changes in length of the specimen are measured by means of a very sensitive and modified form of Lamb's roller type of extensometer. A scale, curved to the requisite radius, is situated at a distance of 21 ft. from the mirrors, and is viewed by reflection through two mirrors mounted on rollers, through a telescope fitted with cross wires. Determinations of extension can be made of the order of one-third of a millionth of an inch per inch of gauge length.

The temperature of the test-piece obviously must be maintained constant within narrow limits. For this reason a sensitive thermostatic control was devised. This is essentially a Wheatsone Bridge arrangement where the variable arm consists of a 0·1 millimeter diameter platinum wire, of 200 ohms resistance, situated between the test-piece and the heating units, and constituting the thermostat. Any change in resistance of this wire due to temperature operates an Electroflo temperature controller having a centre zero, the relay of the controller being actuated by a chopper bar worked from a continuously-running A.C. motor. The position of the needle of the indicator at the moment of action determines the switching in or out of a balancing resistance.



*Top—Battery of " Creep " machines.*
*Bottom—Experimental high-frequency melting furnace.*

*Top—Special high-sensitivity apparatus for measuring the " creep " of steels at elevated temperatures.*
*Bottom—Sulphur print of a section of a large turbine rotor shaft.*

## Metallographical Laboratory

Two laboratories are devoted to the study of crystal structure. One is equipped for macro-examination of the coarser structural features, such as the crystallization in ingots and castings, segregation in forgings, and the direction of the lines of " flow " in forgings and stampings. Permanent records of flow-structure are made from the deeply-etched surface by a direct printing process or by photographic methods, whilst distribution of sulphides is determined by the well-known method of sulphur printing which is applied to complete as well as sectioned forgings, billets and other large masses of steel. An accompanying illustration shows the sulphur print obtained by sectioning a large turbine rotor shaft, and reveals the layout of the structure when a 60-ton ingot is forged into this form. Such work as this is of inestimable value to designers of large-scale highly-stressed steel plant and machinery, and forms an essential link between the design and forging departments.

Micro-examination begins where macro-examination ends and is carried out in a different laboratory. This laboratory is fitted with the numerous processes now employed for investigating the structure of metals. The Leitz polishing apparatus is used for the preparation of most of the sections for examination under the microscope, though hand polishing is still retained where the greatest possible delicacy of touch is required. Visual examinations are carried out with microscopes optically equipped by Winkel-Zeiss. All important structures are permanently recorded by means of a Vickers projection microscope, which gives direct magnifications from three to 6,000 diameters, and two darkrooms are provided for carrying out the photographic work.

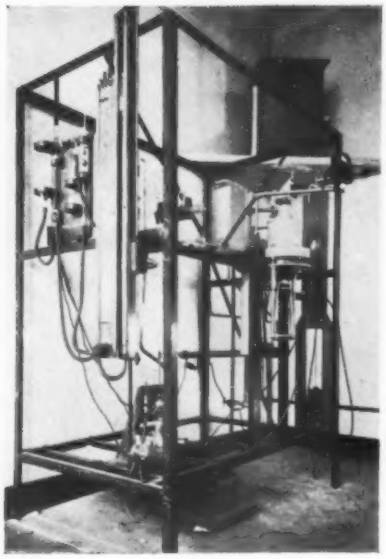
## Physical Laboratory

A knowledge of the physical properties of metals is of paramount importance in the design of structural parts, and the physical laboratory is equipped for carrying out determinations of the various physical constants at normal, sub-normal and elevated temperatures. Determinations of specific gravity, specific heat, thermal expansion, thermal conductivity, electrical resistivity, and magnetic properties, are carried out on the various products of the associated companies and on new experimental compositions. Moreover, in special cases (e.g., for magnetic properties) routine tests are made to check the quality of the work's products.

Included in the work of the physical laboratory is the tensile testing of fine wires and special hardness testing. In the latter connection the necessity for a means of testing the hardness of thin materials and thin skins of surface-hardened articles has long been recognised, and special study has been made of this intricate subject. Other activities of the physical laboratory are the testing of oils ; experiments on steels exposed to various atmospheres at elevated temperatures ; work on the fatigue testing of material in strip form ; on friction and seizing, and on other problems on which data are required for the purpose of determining the best material to use for a particular purpose or of improving the performance of the products of the associated companies.

## Corrosion Laboratories

Since the original development of stainless steel, the subject of corrosion resistance and testing has grown more and more important until, at the present time, the files of the department contain the results of many thousands



*Vacuum hot-extraction apparatus for measuring total " gases " in steel.*

*A portion of the physical laboratory.*

of tests, whilst hundreds of new results are added every year. These tests relate not only to the extended use of existing steels, but also to the design and critical testing of possible new materials. Apart from the work in connection with the special corrosion-resisting steels in the stainless and " Staybrite " type, data are often required on the lower alloys, and even on plain carbon steels. For this work spray tests and atmospheric exposure tests are of considerable importance. The latter are carried out chiefly on the roof of the laboratory which provides an example of very corrosive industrial atmosphere. In these laboratories much work on inter-crystalline corrosion has been carried out, and the well-known copper-sulphate-sulphuric acid solution, now used all over the world as a standard solution for testing for inter-crystalline corrosion, was developed here during the early work in this field.

The descaling of the special corrosion-resisting steels, to remove the oxide formed during rolling and heat-treatment, is an essential process in the production of such materials, and presents a number of problems. The design and testing of processes for the satisfactory descaling of the various types of steel is another of the problems which is dealt with by the Corrosion Department and it will be appreciated that this involves not only the testing of the efficiency of the process from the standpoint of scale removal, but also a critical study of the corrosion resistance of the product after descaling.

High-temperature scaling is actually a branch of corrosion, but the mechanism is quite distinct from that of ordinary liquid corrosion, whilst the methods of testing are also specialised. It is, therefore, conveniently considered separately from the general body of corrosion testing.

The apparatus employed includes electrically-heated furnaces for heating the specimens, flow meters and auxiliary apparatus for the production and measurement of any desired mixture of gases. The most usual mixture employed is obtained simply by burning coal gas with 50% excess air. The resulting mixture is then passed over the steel specimens at any desired temperature up to 1,300° C.

By carrying out several tests it is possible to obtain much interesting information as to the relative behaviour of the standard heat-resisting steels, and to assess the value of new experimental materials. From experience in works practice, it is also possible to relate such tests to actual works conditions, and to deduce a reasonably accurate estimate of the probable life of different materials under certain specified conditions.

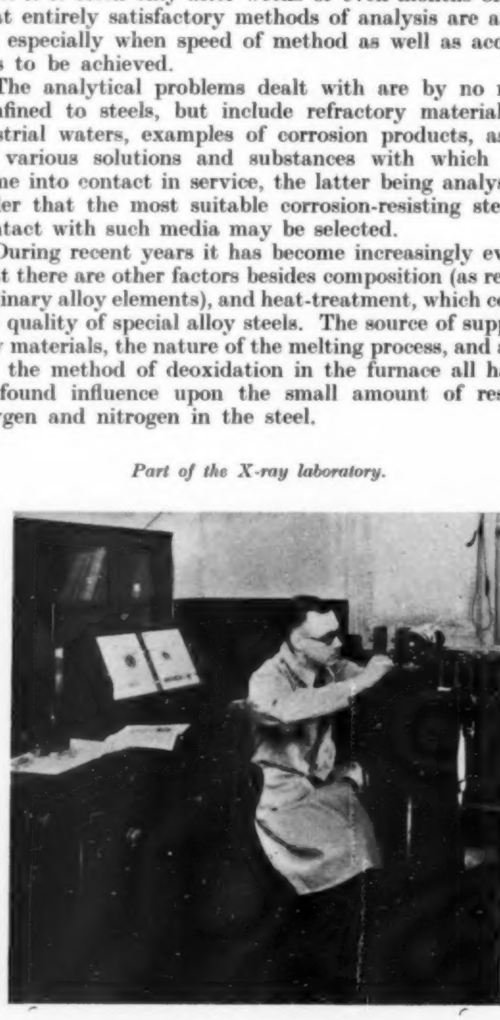
## Chemical Analysis Laboratory

In all departments it is essential to know the precise chemical composition of the materials which are being investigated. To devise a satisfactory means for getting an element into steel is often a most difficult problem, but it is equally a matter requiring very considerable thought and investigation to devise methods for the complete and quantitative separation of such elements, once they have been satisfactorily alloyed. In the development of a new steel it is often only after weeks or even months of work that entirely satisfactory methods of analysis are arrived at, especially when speed of method as well as accuracy has to be achieved.

The analytical problems dealt with are by no means confined to steels, but include refractory materials, industrial waters, examples of corrosion products, as well as various solutions and substances with which steels come into contact in service, the latter being analysed in order that the most suitable corrosion-resisting steel for contact with such media may be selected.

During recent years it has become increasingly evident that there are other factors besides composition (as regards ordinary alloy elements), and heat-treatment, which control the quality of special alloy steels. The source of supply of raw materials, the nature of the melting process, and above all, the method of deoxidation in the furnace all have a profound influence upon the small amount of residual oxygen and nitrogen in the steel.

*Part of the X-ray laboratory.*



Accordingly, two special laboratories are equipped solely for the purpose of studying inclusions. A vacuum hot extraction apparatus incorporating a number of special and novel features is employed for determining the total "gas" content of the steel. The iodine solution method is being used to study the actual form of combination of oxygen, and an apparatus has also been constructed to study the working of the recently-developed chlorine method for the isolation and examination of these non-metallic inclusions.

The development of the nitriding process of hardening steel in ammonia gas has demonstrated the importance of nitrogen in steel. Nitrogen determinations, therefore, form another of the important activities of this department. In this way, the ordinary facilities for analytical work are augmented by equipment for the accurate quantitative determination of these elements and substances, present in all steel, which do not appear in the specification, but, nevertheless, exert a profound influence upon its properties.

*Part of the chemical analysis laboratory.*

### Refractories Laboratories

The Refractories Department contains the most modern apparatus for physical, chemical and petrological testing and research. Special self-recording apparatus for such tests as those of thermal expansion and refractoriness under load has been devised, and high-temperature furnaces have been installed which are capable of testing the resistance of refractories up to temperatures considerably in excess of those which they will actually be called upon to withstand in service.

An X-ray department also forms part of the equipment of the laboratories. X-ray apparatus is used for the crystallographic examination of materials, the apparatus being provided with a flat-film camera for texture photography by either transmission or back-reflection methods and with a cylindrical camera for crystal analysis according to the powder method of Debye and Scherrer, or by the Seemann-Bohlin back-reflection technique. Work within the scope of this apparatus includes examination of the condition of the grain structure of different steels, as well as investigations into the constitution of different alloy systems, whereby their equilibrium diagrams may be derived from changes in lattice dimension and the appearance of new phases. The utility of X-ray methods is not, however, confined to metallic materials, and applications can be made of this method for examining the structure of refractory materials and slags.

# The Influence of Alloying Elements on Steel

*Results of two investigations are given on the effect of alloying elements on the properties of steel, particularly on their properties at elevated temperatures. In one the effect of titanium on a chromium steel is discussed, while the second deals with the effect of phosphorus on steels for use at high temperatures.*

TWO recent investigations which have been carried out in the United States deal with the effect of alloying elements on the properties of steel and particularly on their properties at elevated temperatures. G. F. Comstock and C. L. Clark[1] at the University of Michigan, investigated the effect of titanium on some properties of 17·5% chromium steel, and H. C. Cross and D. E. Krause[2], at the Batelle Memorial Institute, Columbus, Ohio, experimented with the effect of phosphorus as an alloying element in steels for use at elevated temperature.

### Effect of Titanium in Chromium Steels

In the first-mentioned investigation, four steels containing approximately 17·5% of chromium and 0·2 to 0·3% of carbon, and varying amounts of titanium were prepared in a high-frequency induction furnace, and after casting at 1,620° C. were forged into $\frac{7}{8}$-in. round bars. The composition of the steels was as follows :—

| Steel. | C. | Cr. | Mn. | Si. | Ti. |
|---|---|---|---|---|---|
| A | 0·22 | 17·85 | 0·57 | 0·38 | — |
| B | 0·30 | 17·75 | 0·70 | 0·91 | 0·25 |
| C | 0·21 | 17·27 | 0·68 | 0·77 | 1·11 |
| D. | 0·22 | 17·65 | 0·69 | 0·77 | 1·97 |

Brinell hardness tests made on these steels as forged, had after annealing for two hours at temperatures varying from 790° to 945° C. followed by slow cooling in the furnace, showed steels C and D. containing over 1·0% titanium to have a hardness of 137 after forging, and that this hardness remained unchanged after annealing. The other two steels had forging hardnesses of over 400, and an annealing temperature of 850° C. was necessary to soften them to 200 Brinell. Short-time tensile tests carried out at temperatures of 18°, 535°, 650°, and 760° C. after forging and annealing at 900° C. showed titanium to improve some of the elastic properties at high temperatures and particularly the limit of proportionality at 535° C.

Titanium improved the resistance to oxidation of these steels at 870° and 980° C., and 0·25% of titanium seemed to be sufficient for a marked improvement at 870° C. With higher titanium the oxidation at 980° C. was localised. These results were obtained from oxidation tests conducted in triplicate at 650°, 760°, 870°, and 980° C., using cylinders $\frac{3}{4}$ in. dia. by $\frac{1}{2}$ in. long heated in an electric muffle for 1,000 hours in still air.

Creep tests were made on the four steels by a method which complied with the requirements of the A.S.T.M. Tentative Standard. Test specimens were heated to 595° C., and a stress of 2·7 tons per sq. in. was applied for 1,000 hours, and from the data obtained the rates of creep were determined at two periods, as shown by the following results.

Rates of Creep Per Cent Per 1,000 Hours.

| Steel. | A. | B. | C. | D. |
|---|---|---|---|---|
| After 400 hours.. | 0·295 | 0·265 | 1·11 | 0·46 |
| After 800 hours.. | 0·295 | 0·265 | 3·98 | 0·68 |

[1] *Metals and Alloys*, 1937. Vol. 8, pp. 42–46.
[2] *Metals and Alloys*, 1937, Vol. 8, pp. 53–58.

Steels A and B have a constant rate of creep, and steel B with the higher carbon content and 0·25% of titanium shows the best resistance to creep. Steels C and D enter the stage of increasing creep rate in less than 800 hours, and steel C is apparently near failure at the termination of the test, and shows a decidedly lower creep resistance than steels with both less and more titanium.

Tensile tests at room temperature were made on the creep-tests specimens to determine the effect of high-temperature creep on the steels. It was found that titanium improved the ductility of high chromium steel after subjection to the creep test—the ductility of the titanium steels being increased by creep testing, while that of the non-titanium steel was lessened. Titanium additions also increased the structural stability of the steels ; for none of the steels containing titanium showed such detrimental structural changes after creep testing at 595° C., as the plain chromium steel showed.

### Effect of Phosphorus

Short-time tensile tests and long-time creep tests were carried out in the second investigation on a series of steels containing 0·21 and 0·35% of phosphorus, and 0·20% of phosphorus with 1·0% of chromium. The data obtained from these tests were compared with the properties of a steel containing 0·17% of carbon, 0·012% of phosphorus. The result of these tests showed phosphorus to raise the tensile strength and yield point of 0·10 to 0·17% carbon steel at temperatures of 400°, 455°, and 510° C. without affecting the ductility. Phosphorus likewise produced better resistance to deformation, when the steels were subjected to a load of 5·5 tons per sq. in. for 1,000 hours at 455° C. In the presence of chromium, phosphorus exerted a greater influence on creep than when alone.

Tests were also carried out to determine the relative effects of phosphorus and molybdenum in imparting creep resistance at elevated temperatures, as well as of substituting phosphorus for a portion of the molybdenum used. Three steels containing 1·0% of chromium, and 0·2% and 0·5% of molybdenum and 0·5% of phsophorus, respectively, were tested at 455° C. for 1,000 hours under a load of 5·5 tons per sq. in., and two steels containing 0·17% of phosphorus, 0·20% of molybdenum, and having 1·0% of chromium in the one, and no chromium in the other were subjected to a similar load at 510° C. for a period extending over 1,000 hours. The general results of these tests showed the important function of chromium in steels for high temperatures, and indicated the molybdenum and particularly phosphorus exert a greater influence upon creep properties, when chromium is present. It would appear, also, that phosphorus acts much like tungsten and molybdenum in bestowing creep resistance to steel, and that phosphorus has the apparent ability to replace at least a portion of the more expensive molybdenum in some steels for high temperature service without materially affecting the creep properties.

Creep tests were also carried out on steels of varying alloy combination to which phosphorus was added. These steels contained varying combinations of chromium, copper, manganese, molybdenum, and silicon, and were tested at 455° C. and 510° C. under loads varying from 5·5 to 12·5 tons per sq. in. Without chromium the creep properties of phosphorus-copper-silicon steel were poor. The copper and silicon appeared to be of no definite help as such, but along with chromium a phosphorus-bearing steel of good resistance was obtained. Higher rates of creep were also obtained from these alloy steels, when oil quenched and tempered than when normalised and tempered, showing that the higher tensile and yield values resulting from oil quenching and tempering were obtained at the expense of creep resistance.

The impact resistance of phosphorus steels as heat-treated, and after creep was determined from Izod and Charpy impact tests made on certain of the steels in their heat-treated condition, and from Izod tests after creep testing. These impact tests indicated that, for service at elevated temperatures where it is important to maintain a satisfactory impact toughness, the phosphorus content can be substantial, but not much above 2·0%, unless it is augmented by other alloying elements such as chromium, copper, and molybdenum, in which case somewhat more phosphorus may be tolerated. Where impact resistance or toughness are of no importance, then, of course, larger quantities of phosphorus can profitably be employed.

## The Discovery of Radium in Canada

The discovery of pitchblende deposits of Great Bear Lake turned world attention towards Canada. In 1900 the area was visited by a Dominion Geological Survey party, and in the official report on this exploration appeared a brief statement to the effect that the rocky shores were stained in places with a pinkish coloured mineral, known to prospectors as cobalt bloom. Thirty years later an experienced cobalt prospector, reading the report for the first time, and knowing the relationship of cobalt bloom and native silver, set out to discover the area described. His journey, and the subsequent development of the silver pitchblende deposits, is one of the triumphs of modern mining.

With a companion he was set down by airplane on the shore of Great Bear Lake in the early spring of 1930. They worked their way along the shore of the lake until they reached Echo Bay. One of the prospectors became snow blind, and the other decided to do some prospecting nearby while his companion recovered. He had the good fortune to find a large vein stained with cobalt bloom, and containing some silver. Following along the vein he saw a small blackish piece of ore about the size of a plum ; it was pitchblende, the ore of radium. Looking more closely he found the vein from which it came. Thus from reading of an old account of a geological exploration, coupled with courage and modern means of transport, Canada became a radium producer. To-day a modern mining plant, capable of handling 100 tons of ore per day and employing over 100 men, is permanently employed.

While the mine was being brought into production a process for treating the pitchblende was being worked out in the Bureau of Mines Laboratory at Ottawa, and a plant for the refining of the pitchblende concentrates was built at Port Hope, Ontario. Operations were begun in May, 1933, and 3 grms. of radium were produced in that year ; 3½ grms. in 1934 ; 8½ grms. in 1935 ; and by November, 1936, the total production had amounted to 1 oz., or 28 grms. The capacity of the refinery is being enlarged, and when complete it will be producing radium and by-products on a relatively large scale.

Until the Canadian industry was established practically all radium ore was found in the Belgian Congo. In 1923 the price of a gramme of radium was about $150,000. At the time Canada began production the price was around $70,000, and as a result of Canadian competition is now about half that sum. The principal use of radium is in the treatment of malignant diseases, which take such an appalling toll of life every year, and we have reason to be proud of the contribution that Canada is able to make to the world's supply.

The Great Bear Lake development has been of importance not only because of the radium silver discoveries, but because of the inspiration it has given to prospecting and mining in the Territories by calling attention to the fact that large scale operations are possible in a region that, prior to 1930, was doubtfully regarded as profitable mineral country because of the problems of distance and communication.

Messrs. Vickers-Armstrongs, Ltd., intimate the appointment to their Board of Mr. A. Dunbar and Mr. A. B. Winder. Both these gentlemen are directors of English Steel Corporation, Ltd.

METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

# Imperial and International Prosperity

AT the time of writing the national festival has reached its climax and the Coronation ceremony has been performed with all its ancient pomp. It has been an occasion for jubilation and rejoicing and, more than a national festival, it has been an imperial festival. Representatives from every country in the British Empire have taken part in what might be termed a celebration of its fundamental institutions in the Empire. The Coronation has, in fact, provided an opportunity for a manifestation of that unity of heart, of spirit, and of ideals which constitute the Empire, and has shown that King George VI belongs to each of the Dominions and Colonies represented with the same fullness as he belongs to Great Britain.

Fortunately, the Coronation of King George VI has taken place at a time of prosperity, and in this respect differs from the Jubilee celebrations of his father, when Britain and the Empire were slowly emerging from a long period of depression. At that time there were significant indications of recovery, but actual reccvery seemed a long way ahead; manufacturers were doing more trade, but the basic industries were little better than during the slump period. To-day, however, Britain is probably more prosperous than she has ever been, the Dominions are recovering, and the Colonies are enjoying advancing commodity prices. This Coronation year, in fact, may be regarded as a prosperity year, which has in a measure contributed to the spontaneity of the celebrations.

Imperial prosperity is one of the most satisfactory developments of the last year or two. Britain has made quite remarkable progress, and Australia, South Africa and New Zealand are equally prosperous. Canada too, seems to have overcome her period of depression and is making rapid strides towards prosperity. India is improving and in the colonies of Malaya, Africa and the West Indies, the rise in prices of raw materials has greatly improved the economic conditions. And the general upward trend of the world's commodity prices is an important contributing factor, the continuance of which will further improve imperial economic activity. The time and conditions, therefore, are particularly favourable for an expansion of Empire trade, and facilities are being afforded for the consideration of this and other matters by holding an Imperial Conference.

### The Imperial Conference

The statesmen of the young nations created by the Statute of Westminster, who have taken part in the celebrations, that is, of Canada, Australia, the Union of South Africa, New Zealand and India, together with those of the United Kingdom and other representatives of the British Empire, are meeting in Conference, and it would be a pity, in the aftermath of the Coronation, if the importance of this meeting was not realised. Many problems will be considered. The representatives will be able to discuss the Ottawa Agreements and their profitable revision, with the object of producing a set of trade agreements likely to reduce trade barriers rather than to increase them. It is gradually being appreciated that with greatly improved conditions the need for high tariffs and quotas as a protection are not now so essential as during the world slump, and an opportunity is provided for a return to freer trading conditions.

Many important factors affecting world peace are connected with trade, and while this Conference will undoubtedly discuss Imperial trade, its effect on world trade should not be overlooked. Many countries continue to regard a condition of self-sufficiency as of major importance, but international prosperity is only possible when conditions are favourable for the interchange of commodities. The economic policy to-day is, in fact, a vital part of the choice between peace and war, for it is universally accepted that no political appeasement is possible without some relaxation of economic protection.

The view has been expressed that the main subject for discussion concerns contributions towards rearmaments. This is foolish because the Dominions will rightly resent any attempt to place them under obligation, but, what is more important, the views of the Dominions on the policy of the British Government in regard to armaments is of vital importance; the unanimous opinion of the Conference that proper action is being taken, not only to safeguard the British Commonwealth, but to promote world peace, would have an enormous influence among the nations of the world. Vital questions regarding the League of Nations will doubtless arise; here again unity of thought and action on the obligations under the Covenant of the League would have a far-reaching influence on improving the status of the League in its deliberations.

This will be the most important Imperial Conference ever held and its success would indeed set the seal of practical achievement upon the Coronation celebrations. Such a success would not depend upon economic agreements alone, although they are important, but upon a sane policy that would contribute to an improvement in world conditions and in world peace. This meeting will make history; it provides an opportunity for broad-mindedness and a useful contribution to the world's problems such as would add lustre to the British Empire and the cause of democratic government. But the question may be asked, in what way can the British Empire contribute to the cause of peace? Surely such a powerful nation with good-will towards all, endeavouring to replace distrust with confidence, will have a steadying influence on Europe. Further, it should be possible to effect a mutual lowering of trade barriers and to make some arrangement for the pooling of natural resources in order to bring back to Europe and the world the healing streams of revived commercial intercourse.

May the statesmen and representatives at this Conference keep before them the words of Mr. Baldwin when he said "Let us dedicate afresh, if need be, ourselves to the service of our fellows, a service in widening circles, a service to the home, to our neighbourhood, to our country, to our province in the Empire, and to the world. No mere service of our lips, but the service of our lives." With this in view the deliberations may well assist the cause of world peace and promote international prosperity.

## The Opening of the Düsseldorf Exhibition

THE Düsseldorf Exhibition, which is a great effort to demonstrate four years of intense development work of the industries of Germany, was opened on Saturday, the 8th May, and will remain open until October.

The Editor of this Journal, probably because of the Journal's high technical standing in the iron and steel and non-ferrous metal industries, was favoured with an invitation to the opening ceremony, and the occasion was well worthy of the special journey taken to Düsseldorf. Great care had been taken in the selection of those invited, and there were very few foreigners in the Hall to listen to General Goering delivering his address.

The area covered by the Düsseldorf Exhibition is practically the same as that covered by the Exhibition at Paris, and it is of special interest because of Düsseldorf being the industrial capital of the Rhineland, in the neighbourhood of which are world-famous manufacturers of heavy iron and steelworks machinery.

The Essen Works of Krupp are not far distant, and in the main Machinery Hall, the name of Demag is prominent because of the large overhead crane installed by that firm.

An exceptionally interesting exhibit of heavy and light machine tools is being made by Schiess Defries, with unique control and other features, and there is a Waldrich planer of quite exceptional dimensions.

Eumoco in the two Machinery Halls are demonstrating forging and other machines, and prominent exhibitors of heavy plant are Maschinenfabrik Sack and Maschinenfabrik Meer.

There is a considerable amount of furnace equipment also being shown and an electric furnace of Demag Electrostahl attracted considerable attention on the opening day.

The opening day of the Exhibition was too close to our press day to enable us to give here a detailed description even of the more important exhibits, and there are indeed many features of engineering interest throughout the entire exhibition.

There were present at the opening, representatives from all the principal German industrial organisations and great enthusiasm was shown. The Düsseldorf Exhibition is a practical manifestation of the healthy enterprise of German industry, and while engineering comprises only a small part of the whole, yet the exhibits are well worthy of the attention of all engineers.

## Aluminium in the Nitric Acid Industry

THE behaviour of aluminium in contact with nitric acid of different concentrations has been investigated by Chevillotte,* the results of which show that there appears to be no permanent passivation of the metal in contact with the acid, but the dissolution in concentrated acid (48° Bé) amounts to only 0·45 gm./m.$^2$ per day, which is about half the value generally regarded as the maximum rate of corrosion in chemical plant of a permanent nature.

The curve of loss in weight against concentration of acid shows a pronounced maximum at an acid concentration of 20° Bé. and falls off practically to zero for the very dilute and the very concentrated acid above 91% for the 99·5% aluminium. The losses in weight are increased 2—5 times for a rise in temperature of 40° C. Care must be taken also in the construction of the apparatus as very rapid corrosion may set in, particularly at faulty welds. The welds must be perfectly sound and no pores should be allowed to remain. The structure of the weld should be as homogeneous as possible. This may be achieved by hammering the weld, the hammering being followed by annealing by warming with a blowpipe flame to 350–400°. In the case of thick welds, hammering and annealing should be repeated several times.

The presence of flux inclusion in the surface of the metal in contact with the acid should be prevented. This is ensured by welding all joints in containers, etc., from the outside. As flux inclusions have a tendency to rise, the surface of the weld should be ground away by means of a portable grinding wheel and then thoroughly washed with hot water prior to hammering. In general, it has been found that oxy-hydrogen welded seams are superior to those welded by the oxy-acetylene flame and that hammer-welds are superior to both, particularly in contact with the hot concentrated acid. The plant, a large number of parts of which are illustrated, is that used at a French chemical works producing nitric acid by the ammonia oxidation process. As far as possible all the plant in contact with the oxides of nitrogen first formed and the nitric acid, is made of aluminium.

Ammonia and oxygen are supplied through aluminium pipes to the chamber containing the catalyst material and in which the oxidation of ammonia takes place. The oxides of nitrogen pass through two cooling towers. In the first a preliminary cooling takes place, while in the second the oxides of nitrogen are liquefied by cooling them by refrigerating brines. Corrosion of the aluminium by the 26° Bé calcium chloride brines is prevented by the addition of 1–2% of sodium chromate. Traces of nitrogen peroxide, which escape liquefaction, are absorbed in an aluminium washing tower. The liquefied nitrogen peroxide is stocked in all-aluminium tanks. The nitrogen peroxide is further converted into nitric acid by oxidation under pressure in an autoclave.

The nitric acid obtained is decolourised by heating in a steam-jacketed tower to 100° to remove the dissolved oxides of nitrogen which are returned to the refrigerating towers, while the purified acid is cooled in an aluminium heat-exchange apparatus and stocked in large aluminium tanks. Aluminium has also been used for a number of minor fittings and accessories. An interesting example of the latter is an all-aluminium, self-starting syphon used for the handling of the concentrated acid. Finally, aluminium tank cars are used, with excellent results, for the transport of the nitric acid in bulk.

* R. Chevillotte, Rev. Aluminium, Feb., 1937, p. 559.

## Standard Ferro-chromiums

THE Bureau of Analysed Samples Ltd. announces the issue of two new standard ferro-chroniums having the following compositions :—

| | Low Carbon, No. 203. | High Carbon, No. 204. |
|---|---|---|
| | % | % |
| Chromium | 69·0 | 71·4 |
| Carbon | 0·08 | 5·09 |
| Sulphur | 0·01 | 0·02 |

The general analysis of the other constituents is also supplied but not standardised.

As usual each sample has been analysed carefully by at least ten chemists representing independent laboratories, and buyers' and sellers' chemists.

The certificate which accompanies each bottle of the standard sample gives an interesting record of the methods of analysis used by each chemist. The orthodox sod. peroxide fusion method was used by the majority of chemists, but in several cases the new persulphate and perchloric acid methods, which have proved to be both quick and accurate, were used.

Other interesting features were a new combustion method and a new perchloric acid method for sulphur.

These standard samples should prove useful to the many chemists in iron and steel and other laboratories where ferro-chronium is analysed to specification. The low carbon sample is recommended to makers of stainless steels.

The standard is issued in bottle containing 100, 50, and 25 grms. each, and may be obtained direct from the Bureau of Analysed Samples, Ltd., 3, Wilson Street, Middlesbrough, or from any of the usual laboratory furnishers.

# Nickel and Zinc Electroplate Finishes for Iron and Steel Components

By E. E. HALLS.

*In this article evidence is given that a preliminary nickel plating improves the quality of electro-zinc coatings from both durability and appearance aspects; it substitutes the zinc flash normally applied prior to the main zinc deposition direct on steel, and the additional cost of applying the nickel underlay is practically negligible.*

NICKEL and zinc are the two most extensively exploited electroplating processes in general engineering. As separate finishes each is popular in diverse established applications, but the advantages to be obtained by combining the two in the one coating—that is, zinc deposited over a preliminary coating of nickel—are not appreciated by so many engineers and electroplaters.

Before discussing this duplex finish, a few notes on the general aspects of the single coatings are appropriate. In the case of ferrous components, obviously protection against rusting is the prime function of the coating, although appearance may also be an essential feature. With nickel a heavy coating is desirable, and to be effective the quality of the plating must be beyond doubt, because it is electronegative to iron. Surface cleaning and preparation must be correct in order to guarantee adhesion, and operating conditions must be scrupulously clean and well controlled to produce deposits free from porosity and inclusions. Deposits of the order of 0·001 in. to 0·002 in. in thickness are usually agreed upon as necessary for efficient service under interior conditions, although important factors, such as assembly, fit and production cost cause very much thinner nickel platings to be employed. The trend to-day is to favour nickel plated directly on iron and steel, in preference to copper/nickel or nickel/copper/nickel platings; the former being a one-bath process, is rather more economic in production, and with modern agitated, filtered, hot nickelling plants is superior to the duplex or triplex finishes (of the same total thickness). Nickel is extensively employed on miscellaneous components without preliminary mechanical preparation of their surfaces, but in the condition they leave the machines. Again, it is deposited on polished surfaces, and finally coloured by mop or straight grained, to give really attractive finishes.

Zinc is electropositive to iron, so that thin coatings afford preservation, although, up to a limit, the thicker the deposit the more extended the protection period becomes. For interior conditions a deposit of 0·0005 in. to 0·001 in. is satisfactory, although a little thinner coating can safely be resorted to if close-dimensional tolerances are involved. Zinc thus proves rather less expensive than nickel in providing a similar order of protective quality, but it falls short of the latter from the artistic viewpoint. However, by taking certain precautions, which are neither complex nor expensive, neat, attractive zinc deposits can be procured, which, although still not comparable with polished nickel for exterior fittings on equipments, contribute considerably towards saleability.

These special steps include a preliminary thin underlay of nickel plate, the use of acid sulphate-zinc solution, the inclusion of a small proportion of aluminium salts, and of an organic refiner in the electrolyte, careful control of plating conditions to ensure uniformity, and assurance that the mains water, used for final washing, does not contain excessive chlorides and sulphates, or, in the latter case, employing a final rinse in distilled water. Considering these one by one, the preliminary nickel does not generally cause additional cost, because it may be very thin and nickel vats are available in most plating shops. In normal practice, a separate zinc flash or strike, or else a copper flash, is

*Fig. 1.—Sulphate-zinc deposit over a nickel underlay.* × 200.

*Fig. 2.—Cyanide-zinc deposit direct on steel.* × 80.

usually employed. Acid-zinc solutions are easier to manipulate than alkaline baths, and the deposits are easier to wash after plating, and retain their light colour, being free from the tendency to darken rapidly. Aluminium sulphate and glucose are the usual additants, and with these present the distribution of the plating approaches that from alkaline-zinc baths. Plating control is a *sine qua non* of all first-class plants. Attention to the natural impurities in the water supply is admittedly a bugbear, but staining due to them occurs in several finishing-shop processes.

The attributes of an undercoat of nickel beneath the zinc plate may, in the writer's opinion, be summarised as follows:

1. Relatively good throwing power enables recesses, inner surfaces of bends and cupped portions of articles to be rapidly covered.
2. Inequalities in the surfaces of the object, scratches, roughness, pores and cavities in castings become better obscured and reflect less in the final zinc-plated component.
3. Nickel plating solutions being acidic in nature are free rinsing, and troubles, especially with castings, of washing free from cyanide plating solution, are greatly minimised or eliminated.
4. Acid zinc-sulphate solutions are logical for the final zinc coatings, and the combination gives a finish generally superior to cyanide-zinc platings (compared on the basis of equal thicknesses), despite the fact that throwing power of the latter is superior. In some obscure manner zinc-sulphate electrolytes seem to cover better over a nickel underlay.
5. A combination of the above factors ensured a zinc finish of better colour. The light bluish-grey, characteristic of zinc-sulphate electrolytes, is produced, no dark areas exist as they do in the more thinly coated regions when copper is used as an underlay, and there is no gradual darkening to a blackish grey as there is with cyanide-zinc deposits, from which it is practically impossible to wash out all traces of alkali.
6. Rust-proofing qualities are considerably improved, so that longer service can be guaranteed than when direct zinc is employed of the same thickness. Alternatively, a somewhat thinner coating can be used for the same service-life.

7. Adhesion is exceedingly good, and does not decrease with "age"; comparison with direct zinc-plated articles produced by various processes generally indicated superior adherence for the nickel/zinc plating.

The artistic attributes of nickel/zinc finishes can only be appreciated by examining samples in comparison with direct zinc plate on iron, and therefore this article concern itself mainly with the durability aspect. Consequently, various results of accelerated corrosion tests are cited to illustrate this feature. These tests were not made on specially plated test-pieces, but on miscellaneous articles having piercings, drillings or forms varying from 0·031 in. to 0·080 in. in thickness. The batch numbers represent articles closely alike in shape.

TABLE I.

SMALL COMPONENTS ZINC PLATED DIRECT ON STEEL FROM ZINC-CYANIDE BATH. SIX SAMPLES OF EACH OF FOUR BATCHES SUBMITTED TO SALT SPRAY TEST.

| Period of Test. | Sample Batch Numbers. | | | |
|---|---|---|---|---|
| | 1. | 2. | 3. | 4. |
| 1 day | Rusting in bends | Traces of rust in bends | Traces of rust in bends | No rusting |
| 2 days | Rust spreading from bends | Rust in bends on all samples | Rust in bends on all samples | No rusting |
| 3 days | No change | Heavy rusting on inside surfaces of bends | No change | Rust in holes |
| 5 days | Inside surfaces of bends all rusted | No change | Inside surfaces of all bends rusted | No change |
| 14 days | No change | 50% of samples showing rust generally | All samples exhibiting rust generally | All surfaces exhibiting rust generally |
| 18 days | Rust spreading to all surfaces | All samples general rusting | — | — |

TABLE II.

SMALL COMPONENTS ZINC PLATED DIRECT ON STEEL FROM ZINC-SULPHATE BATH. SIX SAMPLES OF EACH OF FOUR BATCHES SUBMITTED TO SALT SPRAY TEST.

| Period of Test. | Sample Batch Numbers. | | | |
|---|---|---|---|---|
| | 1. | 2. | 3. | 4. |
| 1 day | No rusting | No rusting | No rusting | No rusting |
| 2 days | No rusting | No rusting | No rusting | No rusting |
| 3 days | No rusting | Rust on inside surfaces of bends | No rusting | No rusting |
| 4 days | No rusting | Two samples generally rusting | General rusting | Rust on edges |
| 5 days | Rust in holes and inside surfaces of bends | — | — | Rust in holes |
| 9 days | Main surfaces of four of six samples still not rusted | All samples generally rusting | — | All samples generally rusted |
| 14 days | Rust developed generally on all samples | — | — | — |

Tables I, II and III, respectively, contain salt spray test results on components zinc plated from cyanide solution, zinc plated from sulphate solution, and given a double coating from nickel and zinc-sulphate solutions. They were all plated to a nominal thickness of zinc of 1,000 milligrams of zinc per square decimetre, and thickness test results on representative samples are given in Table IV. The latter also shows the surface area of the articles in order to better visualise the nature of the work. The salt spray was produced by atomising 20% salt solution in a closed chamber, the atomiser comprising two fine nozzles, one to which salt solution was fed by gravity, and the other through which a gentle blast of clean, compressed air passed. A day's exposure consisted of the working day in the chamber with the spray operating, the night period in the spray-laden chamber with atomiser off, and then rinsing in cold water and drying before examination.

Table IV shows that all zinc thicknesses are commercially of the same order, and that therefore the spray test results are comparable. These are self explanatory in the Tables, although it is difficult to evaluate the finishes to a precise durability ratio. The shape of the articles, and irregularity of throw of the zinc, shielded areas, etc., prevent this. The indications seem quite definite, however, that the nickel/zinc combination is markedly the best, while the sulphate-zinc plating is a little inferior to the cyanide-zinc samples, from the view-point of durability. From the results one is tempted to predict 50% to 100% longer service for the nickel/zinc finish, the comparison, of course, being on the basis of equal average thicknesses of coating.

TABLE III.

SMALL COMPONENTS NICKEL/ZINC PLATED FROM SULPHATE BATHS. SIX SAMPLES OF EACH OF FOUR BATCHES SUBMITTED TO SALT SPRAY TEST.

| Period of Test. | Sample Batch Numbers. | | | |
|---|---|---|---|---|
| | 1. | 2. | 3. | 4. |
| 3 days | No rusting | No rusting | No rusting | No rusting |
| 4 days | Rusting in tiny holes | Some rusting on inside surfaces of bends and in holes | Tiny rust spots on inside surfaces of bends | No rusting |
| 6 days | Some rust on inside surfaces of bends | No change | No change | No rusting |
| 11 days | Little further change | Little further change | — | Rusting in holes, one sample showing rust spots fairly generally |
| 13 days | Inside surfaces of bends fairly generally rusted | Rusting extended on inside surfaces of bends | — | A second sample showing rust spots generally. |
| 15 days | No marked change | No marked change | Rust spots developing near edges of 50% of samples | One more sample rusting generally |
| 20 days | No marked change | No marked change | All rusting near edges, one generally rusting | Little further change |
| 26 days | No marked change | Two samples developing rust generally | Rust developing generally on 50% of the samples | Four samples now generally rusting |
| 33 days | No marked change | Three samples now generally rusting | Four samples now generally rusting | No change |
| 40 days | General surfaces still good, traces of rust on two only | Four samples now generally rusted, two still very good | All samples now developing rust generally | No change, two samples still good |

TABLE IV.

DATA CONCERNING DEPOSIT THICKNESS OF BATCHES OF COMPONENTS USED FOR SALT SPRAY TESTS IN TABLES I, II AND III.

| Table No. | Type of Coating. | Average Thickness of Coating, Milligrams/sq. Decimetre. | | | | | |
|---|---|---|---|---|---|---|---|
| | | Metal. | Test. | Sample Batch Number. | | | |
| | | | | 1. | 2. | 3. | 4. |
| 1 | Cyanide zinc | Zinc | a | 1,280 | 768 | 1,252 | 864 |
| | | | b | 1,200 | 992 | 1,403 | 711 |
| | | | c | 1,058 | 864 | 1,364 | 832 |
| | | | Mean | 1,180 | 875 | 1,340 | 802 |
| 2 | Sulphate zinc | Zinc | a | 800 | 693 | 808 | 1,568 |
| | | | b | 756 | 811 | 917 | 1,213 |
| | | | c | 844 | 915 | 974 | 1,370 |
| | | | Mean | 800 | 806 | 900 | 1,384 |
| 3 | Nickel/Zinc | Nickel | a | 83 | 147 | 111 | 268 |
| | | | b | 111 | 94 | 174 | 84 |
| | | | c | 157 | 133 | 91 | 163 |
| | | | Mean | 117 | 125 | 125 | 172 |
| | | Zinc | a | 803 | 805 | 647 | 642 |
| | | | b | 742 | 992 | 819 | 706 |
| | | | c | 877 | 931 | 723 | 613 |
| | | | Mean | 807 | 909 | 730 | 654 |
| Total surface area square decimetres .. | | | | 0·15 | 0·50 | 0·20 | 0·31 |

Table V gives some water-spray test results; Table VI showing the average thicknesses of electroplate coatings of the batches of components employed, and the approximate average areas for visualising the size. They were again angular components with formed portions, tapped holes, and thicknesses ranging from 0·031 in. to 0·080 in. The test conditions comprised submission to the spray of distilled water, atomised by compressed air, and utilising equipment similar to that for the salt-spray test. A day's test consisted of the day period of 8 hours in the spray, remaining for the night period in the damp cabinet, then washing under cold, running water and drying.

Table VII refers to a second water-spray test, in which water spray and atmospheric exposure alternated—viz., one day water spray as above, one day in external open atmosphere, but sheltered from direct rain. The articles used for this test were taken from the same batches as used for the previous test, so that the data in Table VI for coating thickness appertains also in this instance.

The water-spray tests are useful ones in so far as they are stringent, because they dissolve off the zinc coating fairly rapidly without building up a thick layer of corrosion deposit; also rusting is clearly marked, although at tiny points. On both the water-spray tests the duplex plating of nickel/zinc proved superior to the single coating of zinc from a sulphate bath, despite the fact that the average thickness of plating in the latter case was about 50% heavier.

TABLE V.

WATER SPRAY TEST RESULTS. SIX SAMPLES OF EACH ZINC AND NICKEL/ZINC PLATED STEEL COMPONENTS SUBMITTED TO TEST.

| Period of Test. | Nickel/Zinc Finish. | Zinc direct from Sulphate Bath. |
|---|---|---|
| 1 day | Superficial white deposit formed but not so marked as with salt spray test | Superficial white deposit formed |
| 9 days | (a) The nickel underlay showed very markedly, especially in bends and in centres of large, flat areas | All samples rusted, evidenced by very tiny rust spots generally distributed. Test discontinued |
| | (b) Inside surfaces of one sample rusted | — |
| | (c) Tiny rust spots generally forming on one sample | — |
| 21 days | Tiny rust spots near edge of a third sample | — |
| 24 days | Three samples still unaffected. Test discontinued | — |

TABLE VI.

DATA CONCERNING THICKNESS OF PLATING ON COMPONENTS USED FOR WATER TESTS IN TABLE V.

| | Nickel/Zinc Finish. | Zinc Finish. |
|---|---|---|
| Average thickness of nickel undercoat, milligrams/square decimetres.............. | 224 | — |
| Average thickness of zinc, milligrams/square decimeters .............................. | 952 | 1,680 |
| Approximate average area, square decimetres.. | 0·5 | 0·5 |

TABLE VII.

ALTERNATING WATER SPRAY AND OUTSIDE ATMOSPHERIC EXPOSURE TEST RESULTS. SIX SAMPLES OF EACH ZINC AND NICKEL/ZINC PLATED STEEL COMPONENTS SUBMITTED TO TEST.

| Period of Test. | Nickel/Zinc Finish. | Zinc direct from Sulphate Bath. |
|---|---|---|
| 1 day | Slight superficial white deposit formed | Slight superficial white deposit formed. |
| 9 days | Three samples showed evidence of rusting—two of them in bends, and one on general surfaces | All showed some rust in bends, and three samples tiny rust spots on general surfaces. |
| 21 days | Rusting a little more marked, and a fourth sample badly rusted along edges | — |
| 24 days | Two of the six samples not rusted | Tiny rust spots definitely present on most surfaces, although extent not bad. |

With regard to adhesion, the presence of the nickel undercoat does not, as some might at first sight consider, weaken the finish. On the contrary, it affords a simple expedient for ensuring that adequate adherence is secured. In the case of the articles used for the durability tests, the following observations were recorded:

(a) Samples zinc plated from cyanide baths, on gradually bending through 90° the coating flaked off 90% of the samples tested.

(b) Samples zinc plated from sulphate baths, on gradually bending double (that is, through 180°) the coating tended to powder or flake off the majority of the samples.

(c) Samples nickel/zinc plated from sulphate solutions, all withstood bending double (viz., through 180°) without any impairment of the adherence.

The nominal plating conditions concerned in the finishing of the articles used in the tests were typical of usual practice, and were as follows:

(a) Zinc from cyanide baths.

| | |
|---|---|
| Electrolyte— | |
| Zinc cyanide .. .. .. .. .. | 25 oz. |
| Sodium cyanide .. .. .. .. | 22 ,, |
| Caustic soda .. .. .. .. .. | 16 ,, |
| Water .. .. .. .. .. .. | 1 gal. |
| Temperature .. .. .. .. .. .. | 80/90° F. |
| Voltage .. .. .. .. .. .. .. | 4 volts |

(b) Zinc from sulphate baths.

| | |
|---|---|
| Electrolyte— | |
| Zinc sulphate .. .. .. .. | 60 oz. |
| Aluminium sulphate .. .. | 2 ,, |
| Sodium chloride .. .. .. .. | 2 ,, |
| Glucose syrup .. .. .. .. | 1¼ ,, |
| Water .. .. .. .. .. .. | 1 gal. |
| Temperature .. .. .. .. .. .. | 70/80° F. |
| Voltage .. .. .. .. .. .. .. | 4 volts |

(c) Nickel from sulphate bath.

| | |
|---|---|
| Electrolyte— | |
| Nickel sulphate .. .. .. .. | 30 oz. |
| Nickel chloride .. .. .. .. | 3 ,, |
| Boric acid .. .. .. .. .. | 3 ,, |
| Water .. .. .. .. .. .. | 1 gal. |
| PH value .. .. .. .. .. | 5·5 |
| Temperature .. .. .. .. .. .. | 80/100° F. |
| Current density .. .. .. .. | Approx. 15 amps./sq. ft. |

All the platings concerned (freshly plated) were pale bluish-grey in colour, the sulphate-zinc and nickel/zinc being considerably lighter than the cyanide zinc. They were all fine-grained, reguline deposits, but again the cyanide deposit was rather coarser than the others. The aluminium-sulphate constituent in the zinc-sulphate electrolyte materially assisted in this direction. Fig. 1 is a microphotograph of the nickel/zinc coating at 200 diameters, and Fig. 2, of the cyanide zinc deposit at 80 diameters. The superiority of the former is evident from the view-point of fineness and density.

From the evidence offered in the foregoing, a preliminary nickel plating improves the quality of electro-zinc coatings from both durability and appearance aspects. The reason for the first is a little obscure, but is probably associated with the natural inertness of nickel, which adds to the protective qualities of the coating in areas where the zinc throws poorly. The explanation of the second is the superior covering power of the nickel, and the better washing characteristics of sulphate deposits as compared with cyanide coatings.

The additional cost of applying the nickel underlay is negligible. Firstly, a thin coating serves, 100 to 300 milligrams per square decimetre being a suitable thickness, which involves a plating period of from two to five minutes, according to the plating conditions of current density. Secondly, this operation substitutes the zinc flash normally applied prior to the main zinc deposition direct on steel. Consequently, greater consideration is warranted of this duplex plating, and it is particularly advocated for small, miscellaneous pressings, castings and components, all those into which a special difficulty is anticipated in securing throw of metal plating into the inner portions, and removal of plating solution from casting cavities and recesses.

## Soviet Output of Manganese Ore

IN 1936 the Soviet Union produced 2,840,000 tons of manganese ore, as against 1,734,000 tons in 1934, which then represented about 60% of the entire world output. Foreign consumers of Soviet manganese ore are mainly the big iron and steel producing countries. In 1935, 40% of the imports of manganese ore into the United States came from the U.S.S.R.; 60% of the German imports; 50% of the Italian imports; 69% of the Polish imports, and 25% of the French imports. The Soviet manganese ore deposits are situated in Chiatury, Georgia, and Nikopol in the Ukraine. Their close proximity to Black Sea ports greatly facilitates the export of the ore.

# The Heat-treatment of Structural Steel

## Some Practical Considerations

By LOXLEY

*Results sought in heat-treating practice are determined by the proper combination of the man, the furnace and the material or component to be treated. In this article some of the factors that influence results in practice are discussed, and attention is directed to dimensional changes, preparation for machining, preliminary treatments, and the quenching and tempering of carbon and alloy structural steels.*

THE first part of this article* closed with a few remarks on distortion. The difficulties caused by distortion vary. Persons engaged in the heat-treatment of parts in the rough are not likely to suffer as much inconvenience as others who must quench and temper finished or semi-finished parts. The inconvenience and loss caused by the volume changes taking place during heating, quenching, and tempering, structural steel cannot be denied, and should not be glossed over. The total amount of money spent in this country yearly on straightening operations alone must be no in considerable sum, it is little wonder that production engineers are inclined to grouse.

Special precautions cost money because they always tend to reduce furnace output, increase the labour charges, and often add to the cost through the necessity of providing and maintaining special quenching tools and jigs. The care taken should be governed by the degree of dimensional accuracy required, and the extra cost in the hardening shop carefully balanced against the anticipated reduction in costs during subsequent operations and possible direct economies by reducing the number of rejections.

The troubles caused by distortion can be made into a useful flail with which to belabour the heat-treater, as he often knows to his cost ; but consider for a momemt his difficulties. No steel is thoroughly homogeneous. It is seldom that two consignments of steel are exactly alike although they may be supplied to meet the same specification. The most serious problem bearing on the distortion of steel during heat-treatment is the volume changes that are associated with the heating and cooling of all structural steels. If steel expanded and contracted regularly on heating and cooling the problem of preventing distortion would be simplified, although it would be bad enough when quenching constructional details in which thick and thin sections existed in the same piece. But as the steels we are considering all suffer a contraction on changing from the alpha to the gamma state on heating and an expansion when martensite is formed on quenching, changes opposed to the normal expansion and contraction, respectively, and further slight dimensional changes on tempering, the heat-treater is set a pretty problem.

If it should be of importance to hold distortion to a minimum then at least one preventable cause of distortion should be eliminated, namely, movement effected by stress-release during heating. Annealing before machining is the best preventive ; but annealing may be objectionable on other grounds (ease of machining, quality of finish). An alternative is to normalise and then reheat to the softening temperature, just below the Ac 1, and soak. Soaking in the softening range of temperature will of itself, apart from a previous normalising, remove most of the internal stress set up by previous operations.

A slow enough rate of heating would cause all sections of the part to expand, contract, and then expand again at the same time. Clearly, this rate of heating is too slow to be practical, but the heating rates of different parts of the same piece should be as nearly as possible identical. Most of the steels affected have a low creep strength at temperatures over 700° C., and suitable precautions should be taken to prevent their sagging under their own weight, the slower the rate of heating the more important this becomes.

It is sometimes supposed by persons having only a limited or superficial knowledge of the subject that the exercise of greater care during quenching and the determination of the dimensional changes of a few typical examples should be sufficient to establish the amount and direction of the changes. There is a modicum of truth in the idea, but it is a long way from being the whole story, as anyone holding such views may readily prove for himself by extending his experiments to include a large number of similar specimens, instead of limiting them to a few examples. If the minimum of distortion is essential the hardener must be given some mechanical aid, but to pursue such methods to their logical conclusion would be impossible in many existing hardening shops. One is inclined to ask if heat-treaters have become too stereotyped in their methods, might not something be done to develop steels and methods that would make quenching in molten salt or metal baths of more general use as a means of reducing distortion.

### Preparation for Machining

An important part of the heat-treatment of many structural steels is their preparation for machining, although this only applies to components that are to receive some machining before final heat-treatment. Full annealing is not usually the best for this purpose, because it makes the steel too soft, unless the carbon content is fairly high. In this soft condition the steel is torn rather than cut during any machining operation, this itself gives a poor finish, although finish is often made much worse by steel sticking to the edge of a tool instead of coming away crisply, still further tearing and damaging the machined surface.

For most carbon and low-alloy structural steels normalising gives the best all-round results. Often ordinary air cooling without any special precautions is good enough, but, obviously, the results will not be quite the same if parts of small or medium size are cooled singly or in batches as they are removed from the furnace. The essential thing is to get a finely-crystalline structure with pearlite and ferrite evenly distributed. For most machining operations on steel containing more than 0·25% carbon finely laminated pearlite it to be preferred to sorbite, and with few exceptions troostite and laminated pearlite structures machine freer and cleaner than the corresponding structures in which the carbide exists in the spheroidal or globular forms. The exceptions are the few high carbon steels that can be classed as structural, these are generally at least partly spherodised ; and some soft straight carbon steels that are better machined in the oil or water-quenched condition, although these, too, are often troostitic because the quenching rate is slower than the critical cooling rate.

* Published in the April issue.

As the alloy content of structural steel increases there is generally an increased tendency to air harden. At first the hardening is often local, small grains of martensite existing together with ferrite and troostitic pearlite and sometimes even finely-laminated pearlite in the normalised steel. In this condition the Brinell hardness number may not be greatly affected, but the martensite present will have a serious effect on machining times and tool life. This tendency to form martensite must be controlled by retarding the cooling rate, which can readily be done in continuous furnaces, but not quite so readily in batch-type normalising. The alternative is to reheat the air-cooled parts for a short time so as to temper the small amount of martensite present.

With still higher alloy contents a rather slow rate of cooling becomes necessary so that the softening or tempering treatment after normal air cooling is no longer merely desirable, but now necessary. An alternative to this is to air-cool the complete charge until the coldest part has fallen to about 600° C., and recharge complete into another furnace maintained at a temperature of 550° C./600° C., hold at this temperature until the temperature has equalised throughout, and then cool in air. If sufficient work is being treated one holding furnace will look after the work of two, three, or even more normalising furnaces, and under such conditions this is usually the cheapest method if a continuous furnace is not available.

For the really hard steels, air-hardening nickel-chromium steel, for example, there is only one really satisfactory treatment for everyday use and uniform results, and that is to heat in the softening range, about 630° C. to 650° C. (actually, a rather prolonged tempering treatment). Soaking should be thorough, and the treatment is best applied after a preliminary air cooling (hardening) from a temperature rather higher than would be used for final hardening. This gives a uniform but somewhat larger grain-size which is better for machining than the smaller grains produced at lower temperatures. It is true that good results can be obtained by combining the two treatments, annealing in large furnaces where the cooling rate is very slow ; but the resulting hardness is not usually so regular as that obtained by the previous method.

### Preliminary Treatments

The advisability of applying some heat-treatment as a preliminary to the final heat-treatment is a question that sometimes arises. Such a treatment may be used with the intention (1) of releasing casting or forging stresses or (2) of producing greater homogeneity throughout the mass, and in this way to give improved and more uniform mechanical properties after the final heat-treatment. The ideas behind such treatments are entirely different from those dictating the procedures used to improve machining properties, although most of the treatments used to produce desired machining properties meet the requirements of (1) also. In the remarks that follow it will be assumed that machining is to be done after final heat-treatment, and the discussion is, therefore, confined entirely to the two sections indicated above.

The preliminary heat-treatment (annealing or normalising) of steel castings that are to be quenched and tempered is always advisable. The temperatures used can be higher than those appropriate for hardening-heats and the soaking times can be longer. This promotes more complete balling-up of the non-metallic inclusions surrounding the primary crystals than would obtain at lower temperatures, and probably helps to some extent by diffusion to even out micro-segregation of the elements found dissolved in the ferrite at room temperature. Except, possibly, as a matter of convenience, it is difficult to defend the use of a preliminary treatment if used only for the relief of casting stresses—and the same remark applies equally to stress-release in forgings. Assuming the casting—or forging—to have become cold, stress-release mainly depends on the steel becoming more plastic on reheating, and is almost complete by the time it has reached hardening temperature. It is as easy to use the same methods for reheating for hardening as for a separate treatment, although it may not be as convenient. Very large castings—or forgings—may be exceptions, but with these special precautions are usually taken during the cooling after casting—or forging—and an additional treatment of the kind referred to is probably more often a "safety-first" measure than an absolute necessity.

All wrought-steel retains some evidence of its early history ; seen in the numbers, kind, and distribution of its non-metallic inclusions, and its general and micro-segregations. This interests the heat-treater because of the difference in directional properties inseparable from commercial wrought steel. The ideal condition of most heat-treated forgings would be for them to exhibit identical properties in all directions ; this they do seldom, if ever. The magnitude of the variations between the transverse and longitudinal mechanical properties of a forging is a measure of the care with which the steel has been made and the heat-treatments carried out. The results should be considered relative to the other factors involved – size of ingot and amount of mechanical work.

The steelmaker is justified when he maintains that steel cannot be made without inclusions, but their size and number affects the directional properties of the forged or rolled material. If the inclusions are small in size and evenly distributed they are not particularly harmful, but no prelimary or final heat-treatment can completely remove the influence of numbers of large inclusions drawn out into long threads during hot working. Heterogeneity is likewise a phenomenon inseparable under practical conditions from the solidification of any liquid system that crystallises as a solid solution on freezing. Hot-working a cored solid solution produces a material whose mechanical properties vary according to the relationship between the applied stress and the direction of maximum extension during hot working. It is the object of preliminary heat-treatments of type (2) to obliterate this influence by causing diffusion to take place.

The rate of diffusion depends on the temperature of heating, and at the temperatures usual for the heat-treatment of structural steels is exceedingly slow for elements other than carbon. In endeavouring to assess the efficacy of preliminary treatments, it is essential to compare those that are of a similar type ; the effect of dissimilar preliminary treatments can only be determined after the final heat-treatment has been given. This seems self-evident, but it is mentioned because the value of preliminary homogeneising treatments has sometimes been assumed from data that proved nothing of the sort and did not even permit of a direct comparison being made.

To be really effective preliminary homogeneising treatments must be carried out at quite high temperatures : some 150° C. to 200° C. at least, above the final hardening temperatures. At one time it was common practice to anneal or normalise steel before heat-treating, but as the temperatures used were rarely much higher than the final hardening temperature, and often below the temperature at which hot working was completed, it is doubtful if such a practice could be defended either on theoretical or on economical grounds. As to undesirable structures produced by overheating, reheating for hardening will remove these as effectively as annealing or normalising ; assuming, of course, that the $Ac_3$ is exceeded in each treatment.

### Quenching and Tempering

(1) *Carbon Steels.*—The upper limit of carbon structural steels suitable for heat-treatment may be placed somewhere about 0·6% carbon, if spring steels be excluded, a group that hardly falls within the present review. Manganese is almost as important as carbon in such steels and much carbon steel intended for heat-treating would be improved if its manganese content were increased. Some specifications for medium carbon steel intended for heat-treating place the lower limit of manganese at 0·4%, but this must, on the

whole, have done a considerable disservice to users. There is now a decided tendency towards higher manganese, and some more recent specifications allow up to 1·2%. If the amount is still further increased, as in a number of well-known steels, they are more conveniently considered as low-alloy steels.

Much heat-treated carbon steel never attains its optimum mechanical properties for the reason that it is not first properly hardened. In large sections this is not possible, even by drastic quenching, although it is doubtful if the drastic quenching of carbon steel is ever worth while. If a steel can only just meet the mechanical requirements by resorting to a very drastic treatment a certain amount of dissatisfaction will be experienced in everyday work. Results tend to be patchy and irregular from one consignment to another, small variations in steel quality that would otherwise pass unnoticed being sufficient to upset the hardening.

Carbon steels, for all their limitations as steels for heat-treatment, fill a large number of practical applications where weight is not of great importance, or the stress is low. Wear resistance is improved by increasing the carbon content, and of two steels heat-treated to give the same tensile strength that with the higher carbon (other things being equal) will wear the least, and usually be the more difficult to machine. There is reason to believe that the higher carbon steels have not the same capacity as low carbon steel for damping vibrations, and for this reason their use may be objectionable in parts subject to much vibration in service, although from considerations of wear alone a higher carbon content might be desirable.

Structural carbon steels over a certain section consist almost entirely of troostite (or even pearlite) and ferrite in the quenched condition; therefore it is possible to make use of them in the "as quenched" condition, and save the cost of a tempering operation. Large quantities of carbon steel have been so used, and probably still are, but whilst this method gives a slight saving in the hardening shop, the economy is often more than lost in the machine shop. If such troostitic steels be examined microscopically, they will often be found to contain isolated patches of martensite in the surface layers. This hard martensite rubs away the edges of the tools during machining, and the machined surfaces are often irregular and not true to size; the harder parts of the steel push away the tool more than the soft. A tempering at 500° C. will decompose any martensite without materially lowering the tensile strength of the steel as a whole; the temperature of 500° C. is also high enough to relieve most of the quenching stresses.

There is appended a table in which are the results of some mechanical tests on a medium carbon steel suitable for heat-treatment. The results illustrate well the influence of rate of cooling on the mechanical properties of such a steel. The oil-quenched specimen possesses quite useful mechanical properties in the "as quenched" condition.

THE EFFECT OF COOLING RATE ON THE MECHANICAL PROPERTIES OF A MEDIUM CARBON STEEL.

Material: Carbon Steel. C. 0·45%, Mn. 0·70%.
Form: Black Rolled Bar. 1½ in. diameter.

| Method of cooling from reheating temperature of 800° C./810° C. | Brinell-Hardness No. | Yield-Point. Tons/in.² | Ultimate tensile stress. Tons/in.² | Elongation % in 2 in. | Reduction of Area. | Micro-Structure. |
|---|---|---|---|---|---|---|
| Quenched in cold water. | 555 | — | (Approx. 125) | — | — | Martensitic. |
| Quenched in cold oil. | 269 | 46·8 | 58·7 | 17 | 45 | Troostitic, small amount of ferrite. |
| Quenched in boiling water. | 222 | 30·6 | 47·2 | 22 | 45 | Fine laminated pearlite, and ferrite. |
| Cooled in air. | 187 | 25·0 | 42·5 | 26 | 47 | Fine laminated pearlite, and ferrite. |
| Cooled in furnace. | 170 | 20·8 | 39·9 | 27 | 43 | Fine and coarse laminated pearlite and ferrite. |

* On surface of bar.

(2) *Alloy Steels.*—The chief reason for adding alloys to structural steels intended for heat-treatment is to obtain higher tensile strengths—accompanied by higher elastic limits (usually), higher yield ratios, and higher fatigue limits—whilst retaining a good balance between tensile strength and ductility and impact value. Wear resistance is largely dependent on carbon content, as in carbon steel. There is an almost bewildering collection of alloy steels from which to make a selection – far more than are needed, one cannot help but feel that if their number were halved makers and users, both, would be better served. It is, however, dangerous to condemn an established practice on general grounds alone, there are so many minor factors that are apt to be overlooked until their existence is made painfully evident after a substitute has been introduced.

The heat-treatment of alloy steels is, in the main, simpler than the heat-treatment of carbon steels. Critical cooling rates are lower, and consequently, quenching can be less drastic, and the effect of mass is less marked. The gain from more intense hardening is accompanied by a greater danger of cracking. Surface defects in bars or forgings are always possible starting points for cracks, and they are, therefore, all the more important if present in alloy steel. Large or complicated forgings should not be allowed to go cold between quenching and tempering: this practice will be found to reduce the danger of crack formation. When tempering, those ranges of temperature should be avoided where rapid changes in properties are known to occur, and accurate control of these is therefore difficult. An example is the tempering of chromium stainless steels in the range 550° C. to 650° C. Similarly, dangerous ranges of temperature should be avoided as that between 250° C. and 450° C., or that immediately below the temperature at which the $Ac_1$ would normally occur.

## Nickel as a Catalyst

AN attempt has been made to summarise a very large literature on the preparation and use of nickel, its compounds and some of its alloys as catalysts in a paper, before the recent general meeting of the Electrochemical Society, by Mr. O. B. J. Fraser. Fields touched upon in the paper are, in order of presentation, oil and fat hardening, hydrogen and the oxides of carbon, hydrogenation of hydrocarbons, miscellaneous organic hydrogenations, hydrocarbon purification by hydrogenation, removal of sulphur from hydrocarbon oils by hydrogenation, artificial ageing of distilled liquors, inorganic hydrogenations, dehydrogenation and polymerisation of organic compounds, simultaneous hydrogenation and dehydrogenation, decomposition of carbon monoxide, carbon oxides and hydrocarbons, carbon monoxide and ammonia, carbon monoxide and steam, hydrogen from hydrocarbon gases, condensation, isomerisation, esterification, hydration and dehydration, addition and elimination of halogens, oxidation of carbon, carbon monoxide and organic compounds, drying oils, oxidation of oils and fats, hydrogen and oxygen, oxidation of sulphides, miscellaneous reactions of sulphides, oxidation of sulphur dioxide, ammonia oxidation, oxidation of atmospheric nitrogen, bleaching, waste water purification, absorption, negative catalysis and inhibitors, miscellaneous organic reactions, miscellaneous inorganic reactions and electrochemical processes.

The author also gives a brief historical foreword and a discussion of the types of nickel materials and amounts consumed for catalyst material in North America and in parts of Europe. The paper is concluded with a general discussion of the properties of nickel and nickel compounds that have catalytic interest.

*Monel Notes*, the second number of which has been issued, is a welcome addition to the publications of Henry Wiggin and Co., Ltd. This issue contains useful information on ammonium sulphate plant, uses of Monel and nickel in gas manufacture, gas plant corrosion problems, nickel and Monel in flow meters, and data on the properties of Monel. Copies are available on application to Henry Wiggin and Co., Ltd.

# Iron and Steel Institute

## Annual General Meeting in London

At the recent annual general meeting of the Iron and Steel Institute, held at the Institute of Civil Engineers, London, Sir H. C. H. Carpenter, F.R.S., who occupied the chair at the outset, announced that H.M. King George VI has been graciously pleased to extend his patronage to the Institute, an honour which the Council deeply appreciate.

The report of the Council shows a welcome increase of membership of the Institute, which, on December 31, 1936, was 2,243 ; an increase of 328 during the year, and the largest number yet recorded.

The increase reflects the greater activity in the industry, and is also due, in some measure, to the proposals introduced during the year in accordance with which many companies, subscribing to the Special Subscription Fund of the Institute, are enabled to nominate members of their staffs who are qualified to join the Institute, and to set the amount of their entrance fees and first year's subscription against the amount of the companies' subscriptions to the Fund.

Expressions of regret are recorded by the Council at the death of the Rt. Hon. Lord Invernairn of Strathnairn, a past-president, and of Prof. H. Le Chatelier, hon. vice-president, both of whom were Bessemer Gold Medallists, and several other members of the Institute.

As Mr. Alfred Hutchinson, M.A., the president-elect, had expressed the wish to retain the presidency for not longer than one year, the Council have nominated the Rt. Hon. the Earl of Dudley, M.C., to succeed him in May, 1938. Mr. Henry C. Bond, who has severed his connection with the industry, expressed his desire to retire from the Council, and Mr. E. J. Fox, was elected a member of the Council in his place. The retiring vice-presidents, Mr. C. E. Lloyd, Dr. W. H. Hatfield, F.R.S., and Sir William Larke, K.B.E., were re-elected, as also were the retiring members of the Council, Mr. E. J. George, Mr. J. S. Hollings, Mr. W. J. Brooke, Mr. F. Clements, and Mr. J. E. James.

In a few well-chosen words Sir H. C. H. Carpenter inducted Mr. Alfred Hutchinson, M.A., the newly elected president, into the chair. Mr. Hutchinson, he said, was well known to all the members of the Council, and had been a member of the Institute for 43 years. The new President responded, and expressed the hope that the Institute would have a successful year. A vote of thanks to the retiring President was proposed by Dr. W. H. Hatfield, which was carried with prolonged applause.

A sincere welcome was offered to the member and visitors from overseas. Representatives were present from Belgium, France, Germany, Luxemburg, Spain, United States, and from Poland, which emphasised the international character of the Institute.

The President particularly extended a hearty welcome to their friends from Germany. The members had the pleasantest recollections of the very successful meeting which had been held in Düsseldorf last September. The presence of Dr. Goerens was considered a particular compliment, as he had paid a short visit to England only a week ago for the International Congress for Testing Materials, and the members would like to congratulate him on his election then as president of that body.

The President made the important announcement that an invitation had been received from the American Iron and Steel Institute and the American Institute of Mining and Metallurgical Engineers to hold the Autumn Meeting of 1938 in America, and that the Council, on behalf of the members, had accepted that invitation.

Another interesting announcement was that the Bessemer Gold Medal had been awarded to Colonel N. T. Belaiew, C.B., a distinguished pupil of the late Professor Tschernoff, of the Military Academy, Petrograd, who, during the last 25 years, had published a series of researches which bore on the crystallisation of metals and, in particular, of steel. A Bessemer Gold Medal was also presented to Mr. Aloyse Meyer, whose whole career had been devoted to the technical and industrial development of the iron and steel industry. He had started as an engineer in 1904 at the Hauts Fourneaux et Acieries de Dudelange, one of the first works in Europe, and the first in the Lorraine-Luxemburg district, to adopt the Thomas Gilchrist process, which revolutionised the manufacture of steel on the Continent. Both presentations were made amidst prolonged applause.

### Presidential Address

In the course of his presidential address, Mr. Hutchinson referred to the first visit of the Iron and Steel Institute to the Middlesbrough district in 1869, when the visitors must have seen a fully developed wrought-iron and pig-iron industry in active operation. Following the discovery of ironstone in the Eston Hills, 17 mines had been opened up and 167 blast-furnaces erected. The pig-iron so produced formed the raw material for the foundry trade in the district and in Scotland, and for the wrought-iron trade. The point of technical importance was that the molten pig-iron produced was allowed to cool on the pig-beds, so losing the initial heat, and was sent as cold pig-iron to foundries and forges, in which it had to be remitted to produce finished products, and the finishing operations of a large proportion of the pig-iron output were conducted in other districts.

A very different state of affairs existed to-day, as members will see who visit Middlesbrough in the autumn of this year. The wrought-iron trade has completely disappeared, being replaced by steelworks, in many of which the molten pig-iron is converted into steel without the loss of its original heat, and rolled into finished steel products on the spot, and in some cases there are attached to such steelworks finishing departments in which the essential parts of structural steel buildings are manufactured. Discoveries and inventions in all branches of metallurgy and engineering have effected a great change, which he reviewed at some length. He reminded members that the great improvements now manifest are the direct result of research, to which many great lives in the past had been devoted

Under the auspices of the Institute and the Research Department of the Iron and Steel Federation, active research has been stimulated in every department of the trade. In such research the Cleveland district has played no mean part. Mention was made of Sir Isaac Lowthian Bell, Mr. Windsor Richards, Sir Arthur Dorman, Mr. Benjamin Talbot, Dr. J. E. Stead, who played a great part in laying the foundation of the future prosperity of the district.

He concluded with a few personal references to the memory of his father, who, without previous experience in pig-iron manufacture, on taking charge of a small plant at Skinningrove, turned his attention at once to improving its method of operation in every possible way. He inspired his staff with the desire for progress and economy, and later, when building steelworks, encouraged the adoption of the most modern plant.

### Technical Sessions

Several papers on many complex problems were presented at this meeting, in which were given the results of investigations and researches. Two important reports were also presented : one describing the work of the Committee on

the Heterogeneity of Steel Ingots; and the second, the work of the Coke Research Committees. Extensive examinations of ingots have been carried out and data have been obtained on a number of the more fundamental aspects of the subject, and a very complete report is given of the work done and the present knowledge of many aspects of the subject.

The main objectives of the Coke Research Committees were to devise methods of testing coke which would express its value in the blast-furnace; to investigate the factors determining the quality of coke; and to devise methods of improving the quality of coke in practice. The following are brief summaries of the papers and reports presented:

### Testing and Improving the Quality of Coke

The Midland, Northern and Scottish Coke Research Committees form an integral part of the research organisation of the iron and steel industry, and are committees of the Blast-Furnace Committee of the Iron and Steel Industrial Research Council. The Midland Committee was formed in 1926 at the instance of Prof. R. V. Wheeler, of Sheffield University. It was formally constituted after a conference at which representatives of the Midland, Northamptonshire and Lincolnshire Iron Masters' Associations were present. The Committee was subsequently enlarged and now includes representatives of the coal, coke, chemical, gas, iron and steel industries. The Chairman of this Committee since its inception has been Mr. W. J. Brooke, of Scunthorpe. The Northern Committee was formed in 1926 under the chairmanship of the late Dr. H. Peile; the present Chairman is Mr. A. H. Middleton, of Consett. The Scottish Committee was formed in 1928 under the chairmanship of Mr. M. Brand, the work being supported by Scottish coal, iron, and steel-making interests; the present Chairman is Mr. T. H. Thorneycroft.

The Coke Research Committees carry out their work in laboratories housed in the University of Sheffield, Armstrong College, Newcastle, and the Royal Technical College, Glasgow, and the Report* presented at this meeting of the Iron and Steel Institute summarises the work which has been carried up to December, 1936. The individual problems which have been investigated have been classified under suitable headings and arranged as far as possible in a logical sequence.

As a result of investigations the present position with regard to the testing of coke, the determination of quality, and methods of improving quality, are reviewed. Much has been done, but each coalfield presents its own individual problems, and this has naturally led the various Coke Research Committees to attack the problems in their own districts in various ways. In one section of the Report it is shown that despite the considerable increase in demand for coke during the past year and the increasing scarcity of good coking coals, there has not been the serious deterioration in the average quality of coke in the Midland area during this period that has been experienced in the past during periods of increased demand; and this in itself is indicative of the value of the co-operation of makers and users in the work of these Committees.

Although many problems to be dealt with vary considerably from one district to another, certain aspects of the work are common to all three Committees, and in order that these may be dealt with more effectively, the Blast-Furnace Committee has recently formed a Coke Co-ordinating Committee, consisting of the Chairmen, Honorary Directors, and Technical Officers of the three Coke Research Committees, with Dr. F. S. Sinnatt (Director of Fuel Research) as Chairman, and Mr. E. C. Evans as Technical Secretary. One of the first activities of this Committee was to consider the present Report in detail, and has already been of service in assisting the Committee to formulate a programme of research on a national basis, which, while making full provision for the study of the problems of the individual producing districts, has had a full regard for those fundamental aspects that require consideration. This Report will be of service to all interested in coal carbonisation—not only in directing attention to the work that has been done by the Committees, but also in bringing to the notice of scientific workers in this and other countries some of the problems which await solution.

* "The Work of the Coke Research Committees of the Iron and Steel Industrial Research Council." By E. C. Evans and J. M. Ridgion. Published at the Office of the Iron and Steel Institute, 28, Victoria Street, London, S.W. 1. Price, 10s.; Members, 5s.

### Testing Corrosion Resistance of Stainless Steel

On stainless steels three kinds of corrosion are found—even corrosion over the whole surface, local attack, and intercrystalline corrosion. Fairly reliable corrosion testing methods are available for determining surface and intercrystalline corrosion, but the methods generally used for testing the resistance of these steels to local attack, or pitting, are regarded as imperfect. In connection with this latter type of attack a new method of testing has been developed, and is described in this paper by Dr. Sven Brennert. By means of this corrosion testing method numerical values can be given for the resistance of stainless steels to the formation of pits.

The method described consists in the determination of the anodic potential which can be applied to a metal surface without any "break-through" taking place. The potential is measured against that of a saturated calomel electrode. The author discusses the practicability and the defects of the method, and the "break-through" potentials for some stainless steels are given.

### The Resistance of Metals to Corrosion-fatigue

The experiments described in this paper by Dr. H. J. Gough, M.B.E., and Mr. D. G. Sopwith, B.Sc., form part of a related series designed to afford information on certain general aspects of corrosion-fatigue which had hitherto escaped attention.

To attain the dual objective of obtaining data of direct value in aircraft design, as well as an understanding of the general characteristics of corrosion-fatigue, the materials chosen cover a range commonly used in aircraft construction. Much experimental attention has been devoted to corrosion-fatigue phenomena by many investigators in many parts of the world, but with the exception of a few tests, in which cycles of reversed torsional stresses were employed, reversed flexural stresses have almost entirely occupied attention. Further, the fatigue resistance in air is commonly used as the standard of comparison, although much evidence existed indicating that fatigue tests made in the atmosphere did not necessarily give the optimum resistance to cyclic stresses.

Six materials have been tested: 0·5% carbon steel (cold-drawn streamline wire), three "non-corroding" steels of various compositions, duralumin, also a magnesium alloy containing $2\frac{1}{2}$% of aluminium. The fatigue resistance of each material has been determined both in air and when subjected to an air-borne salt spray, under two types of cycles of direct stresses: (*a*) repeated tensile stresses (varying from 0 to a maximum tensile stress), and (*b*) fluctuating tensile stresses having a fairly high mean stress value. The resistance of these materials to cycles of reversed direct stresses, both in air and in salt spray, have previously been determined and recorded.[1]

The results show that, as in air, the fatigue resistance of a material in a corrosive environment is considerably influenced by the mean stress of the applied cycle. As in the case of reversed stresses, no corrosion-fatigue limit was indicated for any of the materials. If the range for any given endurance is plotted against the mean stress, the form of the curve obtained is in general similar to that obtained in air, using the fatigue limit in place of the endurance range.

[1] Gough, "Corrosion-Fatigue of Metals," *Jour. Inst. Metals*, 1932. No. 2, p. 17.

## The Allotropy of Iron

The transformations of iron are the subject of an extensive literature, yet very little has been written, up to the present, on the mechanism whereby such transformations are effected. In this paper by Hans Esser the results of investigations on various types of iron show that the $A_3$ transformation temperature rises as the purity of the material is increased ; simultaneously, the intensity of transformation decreases. Hydrogen causes the $A_3$ point to be " doubled " ; on removal of the hydrogen by annealing at high temperatures *in vacuo* this effect disappears again. The experiments show that, with the means at present available, it is not possible to increase the degree of purity of iron to such an extent that the allotropic transformations disappear. On the other hand, the research on the influence of the degree of purity on the limiting concentration of the closed $\gamma$ field in the Fe–W, Fe–Cr and Fe–Si systems indicates that with absolutely pure iron the $\alpha \rightleftharpoons \gamma$ transformation does not occur.

With regard to the true structure of iron, which, like that of other materials, is probably of a mosaic-like character, it is assumed that the impurities ($Fe_3C$, $Fe_2N$, $Fe_xH$) are embedded in the boundaries or interstices of the crystalline " blocks," and thus cause the tetragonal expansion of the $\alpha$ lattice with the axial ratio $c/a = 1{\cdot}0$ into the $\gamma$ lattice with the axial ratio $c/a = 1{\cdot}41$. Iron, therefore, possesses not true but imposed allotropy.

## The Influence of Silicon, Phosphorus and Manganese on Nitrogen-Hardening Cast Iron

The experimental work described in this paper by Mr. J. E. Hurst was undertaken with the object of ascertaining the effect of the elements silicon, phosphorus and manganese, within certain percentage ranges, on the susceptibility to nitrogen-hardening of aluminium-chromium alloy cast irons of a type now known as Nitricastiron.

Within the ranges of chemical composition examined, the results of these experiments show that a variation in the silicon content has no effect upon the degree of surface hardness obtained during nitrogen-hardening. The amount of silicon present does appear to have an influence upon the depth of penetration, the higher the silicon content, the lower being the depth of penetration. The experimental results demonstrate also that the effect of chromium is in the direction of ensuring greater depth of penetration, rather than affecting the degree of the surface hardness.

In the case of phosphorus, results show that with this element in excess of 0·20% a reduction in surface hardness is obtained, but the total depth of penetration of the hardening effect is not altered. Manganese appears to be without effect upon either the hardness or the total depth of penetration.

Nitrogen-hardening at the three temperatures of 500°, 530° and 600° C. was examined in the case of the silicon series of specimens. It is of interest to note that the temperature of 550° C. was accompanied by the highest and most uniform hardness results, and the depth of penetration increased with an increase in the hardening temperature. In a like manner the magnitude of the growth increased with increasing hardening temperature, and the somewhat remarkable result was obtained that this growth appears to be independent of the depth of penetration, and also to be unaffected by the silicon and chromium contents. The growth at 600° C. was of a visibly substantial order, and was accompanied by swelling and cracking at the corners and edges of the specimens. The case obtained at this temperature was extremely brittle and friable, and it is possible that the low surface hardness values are in a large measure to be ascribed to this brittle and friable condition.

The structural characteristics of the specimens examined have been recorded, and are those obtained after submitting the specimens to a uniform annealing treatment. It is recognised that the structural characteristics of cast iron suitable for nitrogen-hardening are of importance, but further investigation of the effect of other heat-treatments upon the structure and the nitrogen-hardening properties has not yet been completed.

## The $\beta_M$ Transformation in Manganese-Rich Iron-Manganese Alloys

The investigations described in this note by Dr. Marie L. V. Gayler and Mr. C. Wainwright, M.Sc., is a continuation of the systematic research on alloys of iron at the National Physical Laboratory, under the auspices of the Alloys of Iron Research Committee, eleven sections on which have previously been published.

This investigation was undertaken in order to explain discrepancies between the results of Ohman, of Walters and Wells, and those previously published by the present authors. X-ray examination of two iron-manganese alloys, containing 71% and 74% of manganese, previously annealed at 573° C., and consisting of $\alpha_M$ only, were heat-treated at successively higher temperatures, quenched and then submitted to X-ray analysis. The results obtained were in agreement with those of Walters and Wells. On the other hand, X-ray analysis of the specimens annealed at 750° C., slowly cooled to and quenched from lower temperatures, confirmed the present authors' previous results. It is shown, therefore, that manganese-rich iron-manganese alloys consisting of the $\beta_M$ phase may exist in a metastable state at temperatures below that at which the $\alpha_M$–$\beta_M$ transformation takes place on heating, and that the upper limit is that found by Walters and Wells, and the lower that obtained by the present authors.

It is noted that a similar hysteresis loop occurs at the iron end of the iron-manganese diagram.

## Effect of Phosphorus on the Mechanical and Corrosion-resisting Properties of Low-carbon and of Low-alloy Structural Steels

The properties in the normalised and annealed conditions of a large variety of carbon and low-alloy steels with low- and high-phosphorus contents have been determined, and are reviewed by Mr. J. A. Jones, M.Sc., with the object of assessing the relative values of different compositions in meeting the requirements of the British Standard Specification for high-tensile structural steels (37—43 tons per sq. in.), and in conferring other characteristics which are desirable in steel for structural purposes.

The results confirm the generally accepted conclusion that the carbon content must be kept low in high-phosphorus steels, and that the addition of phosphorus alone to a low-carbon steel will not produce the adequate tensile strength in association with other properties necessary in structural steels—*e.g.*, absence so far as possible of notch-brittleness, low-temperature brittleness, strain-age-embrittlement and air-hardening tendency, together with improved resistance to corrosion. The tensile strength of a low-carbon steel cannot be raised above 34 tons per sq. in. by the addition of phosphorus without marked deterioration of the notched-bar impact value.

In the presence of other alloy elements phosphorus behaves in precisely the same manner as in plain carbon steels, but the phosphorus content at which undesirable properties appear may be raised. In this respect chromium exerts the most marked influence. For other reasons, the presence of copper is advantageous.

With the restriction on the carbon content imposed by high phosphorus contents, the alloy content must be higher than would otherwise be necessary, and in order to obtain tensile strengths of over 35 tons per sq. in., a high-silicon content (the hardening effect of which does not depend on its association with carbon) must also be present. In such a steel containing 0·15% of phosphorus, a satisfactory notched-bar impact figure is not retained when the tensile strength reaches 37 tons per sq. in. The application

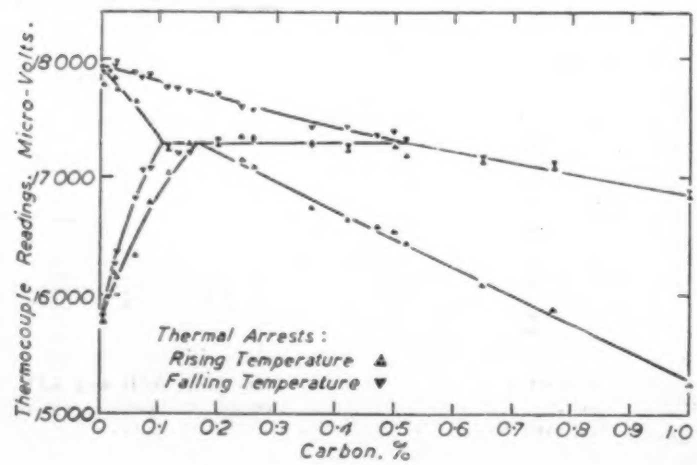
of high-phosphorus steel must, therefore, remain strictly limited to purposes for which the highest tensile properties are not required, and in this limited field for lower-tensile material its use may be regarded as permissible rather than preferable. The limitations are avoided by the use of a normal phosphorus content. The carbon content is then no longer so restricted, and by comparatively low alloy additions a tensile strength of 37 tons per sq. in. may easily be obtained without introducing any risk of the disadvantages which may accompany the presence of a high-phosphorus content.

No evidence has so far been found to indicate that a high-phosphorus content confers on the steel any useful increase in resistance to corrosion. Such effects as were observed in high-phosphorus steels were accounted for by the simultaneous presence of alloy elements.

## The Iron-Carbon Constitutional Diagram

This preliminary investigation, reported by Dr. Frank Adcock, was restricted to the high-temperature thermal analysis of 24 alloys, with carbon contents ranging from 0·003% to 1·01%. This work is to be supplemented by a further investigation at a later date, and the results given in this paper are regarded as tentative. Although there are definite limitations associated with the method of thermal analysis, it appears unlikely that the shapes of the phase-fields of the constitutional diagram, as determined by this means, will require serious modification in this instance.

The alloys were prepared from high-purity materials. A valve-energised, high-frequency furnace was used for the experiments, the alloys being prepared and maintained under high-vacuum conditions. As a result of this investigation a portion of the iron-carbon constitutional diagram, falling within the composition limits of 0·003% to 1·01% of carbon and an approximate temperature range of 1,550° to 1,300° C. is defined. This region of the diagram includes the δ-phase field and the duplex-phase fields associated with the peritectic horizontal, which is found to intersect the liquid curve at a composition corresponding with 0·51% of carbon.




*The Iron-carbon diagram.*

The part of the iron-carbon constitutional diagram defined is reproduced in the accompanying figure. The general disposition of the phase-fields is similar to that postulated by previous authors, but the shape and extent of the fields have been modified.

The δ phase is not formed in alloys richer in carbon than that corresponding in the diagram with the point of intersection of the peritectic horizontal and the liquidus. This limit, which in the author's diagram is placed at 0·51% of carbon, is of special interest, since the γ phase separates directly from the liquid during the freezing of an alloy containing a higher amount of carbon.

## Effect of Protective Coatings on the Corrosion-Fatigue Resistance of Steel

This paper, by Mr. D. G. Sopwith, B.Sc., and Dr. H. J. Gough, M.B.E., describes the results of an investigation of the protective effect of various types of coating on the resistance of 0·5% carbon cold-drawn steel, as used for streamline wires of aircraft, when subjected to alternating stresses in the presence of a spray of salt water. The investigation forms part of the joint programme of research on corrosion-fatigue, which has been in progress during the last few years at the National Physical Laboratory and the Royal Aircraft Establishment.

The material used for these tests was ½ in. diameter steel wire to British Standard Aircraft Specification 5*W* 3 (Streamline Wire Steel). The specified and actual compositions and tensile strengths of the material used were as follows :

| Composition. | B.S.S. 5*W* 3. | Actual. |
|---|---|---|
| Carbon ............ % | 0·5–0·6 | 0·50 |
| Silicon ............ % | Not more than 0·3 | 0·110 |
| Manganese ............ % | 0·5–0·9 | 0·54 |
| Sulphur ............ % | Not more than 0·05 | 0·020 |
| Phosphorus............ % | Not more than 0·05 | 0·010 |
| Tensile strength ............ Tons/sq. in. | 52–62 | 63·3–66·6 (See Table III) |

The material had therefore a somewhat high-tensile strength. It was supplied by the R.A.E., Farnborough, in the form of straight bars, 10 ft. in length, cut from a coil and straightened.

The material (except in the case of the aluminium-coated specimens) was tested in both the cold-rolled condition (as specified) and after normalising, the specimens being cut to length and cooled in air from 850° C. after

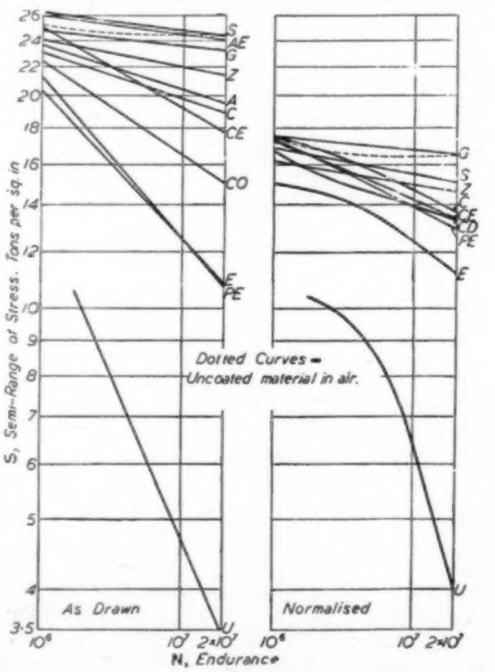



*Fig. 1.—Summary of corrosion fatigue S/N diagrams.*

20 mins. soaking ; the heat-treatment was carried out at the R.A.E., Farnborough.

The fatigue resistance, under reversed bending stresses in air and in salt spray, of streamline wire steel have been determined, using the material in both the as-drawn and normalised conditions uncoated and with the following types of coating :

(1) *Zinc*, applied by (*a*) galvanising, (*b*) sherardising, (*c*) electrodeposition.

(2) *Electrodeposited Cadmium*, (*a*) alone and with supplementary coatings of (*b*) enamel and of (*c*) boiled linseed oil.

(3) *Sprayed Aluminium* (*a*) with enamel and (*b*) without enamel.
(4) *Phosphates* plus enamel.
(5) *Enamel* only.

The results of the fatigue tests are summarised in Table XIV, in which are given the fatigue limits in air and the endurance limits in salt spray at 1, 10 and 20 million cycles. The latter are obtained from a series of curves, which, for the purpose of easier comparison, are plotted on one diagram which is reproduced in Fig. 1.

The main results indicate that the corrosion-fatigue resistance of streamline wire steel in salt spray may be increased by the application of galvanising, sherardising, or aluminium-spraying plus enamelling to such an extent that the endurance limit at 20 million cycles is little, if at all, inferior to the fatigue limit of the uncoated material in air. Aluminium-spraying alone, also cadmium-plating, whilst not so good as the above, reduce the decrease in fatigue resistance to about 20% in place of about 80% when uncoated. The results with cadmium-plating are *not* improved by the addition of organic coatings (enamel or boiled linseed oil), the effect of which may indeed be harmful.

A coating of enamel produces a considerable improvement in the corrosion-fatigue resistance, but not to an extent comparable with the metallic coatings. Phosphate treatment before enamelling produces little further improvement. Zinc-plating and aluminium-spraying do not decrease the fatigue resistance of the steel in air; galvanising, sherardising and cadmium-plating give slight decreases, not exceeding 10% at most.

No indication is given, at any rate up to 20 million cycles, of the existence of any corrosion-fatigue limit, the log $S$/log $N$ curves becoming straight after from less than 1 to 10 million cycles. The slope of the straight portion of the curve gives a good indication of the corrosion-fatigue resistance of the material, the actual value of the endurance limit being also affected by the initial fatigue strength.

TABLE XIV.

SUMMARY OF THE RESULTS OF FATIGUE TESTS.

| Type of Coating. | As-Drawn. | | | | | | Normalised. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fatigue Limit in Air. | | Endurance Limits in Salt Spray. | | | | Fatigue Limit in Air. | | Endurance Limits in Salt Spray. | | | |
| | Tons per Sq. In. | %. | $10_6$ Cycles. Tons per Sq. In. | $10_7$ Cycles. Tons per Sq. In. | 2 × $10_7$ Cycles. Tons per Sq. In. | 2 × $10_7$ Cycles. %. | Tons per Sq. In. | %. | $10_6$ Cycles. Tons per Sq. In. | $10_7$ Cycles. Tons per Sq. In. | 2 × 10 Cycles. Tons per Sq. In. | 2 × $10_7$ Cycles. %. |
| None (U) | 24·5 | 100 | 10·0 (2 × 106) | 4·7 | 3·5 | 14 | 16·4 | 100 | 10·3 (2 × 106) | 6·4 | 4·0 | 24 |
| Enamel (E) | 22·8 | 93 | 20·5 | 12·5 | 10·8 | 44 | 17·2 | 105 | 15·0 | 12·5 | 11·2 | 68 |
| Galvanising (G) | 24·7 | 101 | 24·8 | 23·6 | 23·2 | 95 | 14·8 | 90 | 17·6 | 16·8 | 16·6 | 101 |
| Sherardising (S) | 22·8 | 93 | 26·2 | 24·8 | 24·5 | 100 | 14·8 | 90 | 16·9 | 15·5 | 15·2 | 93 |
| Zinc-plating (Z) | 24·4 | 100 | 24·0 | 22·0 | 21·4 | 87 | 16·1 | 98 | 16·2 | 15·0 | 14·7 | 90 |
| Cadmium-plating (C) | 22·8 | 93 | 23·0 | 19·8 | 18·9 | 77 | 15·2 | 93 | 17·4 | 14·8 | 13·7 | 84 |
| " + enamel (CE) | 23·2 | 95 | 25·0 | 19·1 | 17·7 | 72 | 15·8 | 96 | 17·2 | 14·3 | 13·5 | 82 |
| " + oil (CO) | 21·8 | 89 | 22·3 | 16·4 | 15·0 | 61 | 15·8 | 96 | 16·7 | 14·0 | 13·4 | 82 |
| Phosphate treatment + enamel (PE) | 22·8 | 93 | 21·2 | 12·5 | 10·7 | 44 | 17·8 | 108 | 17·3 | 13·8 | 12·9 | 79 |
| Aluminium spray (A) | 55·8 | 105 | 23·6 | 20·4 | 19·5 | 80 | — | — | — | — | — | — |
| " + enamel (AE) | 25·2 | 103 | 26·0 | 24·6 | 24·1 | 98 | — | — | — | — | — | — |

## Properties of Commercial Steel Sheets containing Copper, Manganese, Chromium and Phosphorus

An objection to the use of thinner sections of higher-strength steel to obtain weight reduction is that unless the corrosion resistance increases *pari passu* with the mechanical properties, maintenance and replacement costs may be increased.

Sir Harold Hartley, Vice-President and Director of Research of the London, Midland and Scottish Railway, during a recent visit to the United States of America, was impressed by the attempts being made to deal with this problem by the use of a steel containing small additions of copper, chromium, phosphorus and silicon. The investigation described in this paper by Mr. S. C. Britton, M.A., was therefore undertaken in order to assess the superiority of such a steel over related alloy steels, and over steels in ordinary use on the L.M.S. Railway.

Reference is made to the results of previous investigations in England, Germany and America which indicate that high phosphorus, in combination with copper, may produce steels having good mechanical properties and a corrosion resistance somewhat greater than that of ordinary copper-bearing steel. The investigators who have dealt with this influence on the corrosion resistance have all suggested that the beneficial effect is due to a development or increase of the protective quality of the rust layer which forms on the steel.

Six steels, all commercial products in sheet form, have been examined. Their composition, grain size and hardness values are shown in Table I. The two materials with high-phosphorus contents have a remarkably coarse "inherent" grain size, which would normally suggest a relatively low-impact resistance. Erichsen test results, however, indicate no shortage of ductility. Specimens AJQ, AJR and AJV undergo a notable decrease of hardness on heating, which indicates that they are slightly strain-hardened, due to rolling.

TABLE I.

DETAILS OF THE STEELS TESTED.

| | AJQ. American Copper-Chromium, High-Phosphorus Steel. | AJR American Copper-Manganese Steel. | AJW. British Copper-Chromium, High-Phosphorus Steel. | AJX. British Copper-Chromium Steel. | AJU British Steel of Ordinary Quality. | AJV British Steel of Ordinary Quality. |
|---|---|---|---|---|---|---|
| Carbon .....% | 0·12 | 0·25 | 0·040 | 0·15 | 0·09 | 0·06 |
| Silicon ......% | 0·86 | 0·19 | 0·94 | 0·07 | 0·05 | Trace |
| Manganese ..% | 0·27 | 1·34 | 0·24 | 0·65 | 0·48 | 0·38 |
| Copper......% | 0·41 | 0·27 | 0·42 | 0·31 | 0·22 | 0·09 |
| Chromium ..% | 1·15 | Trace | 0·80 | 0·65 | Trace | Trace |
| Sulphur.....% | 0·025 | 0·012 | 0·016 | 0·028 | 0·04 | 0·026 |
| Phosphorus..% | 0·163 | 0·020 | 0·173 | 0·040 | 0·016 | 0·017 |
| Aluminium ..% | 0·002 | 0·003 | 0·001 | 0·001 | 0·001 | 0·002 |
| Thickness of sheet .... In. | 0·072 | 0·072 | 0·040 | 0·035 | 0·060 | 0·065 |
| Grain Size— Inherent* ... | >1 | 4–5 | >1 | 3 | 4† | 3 |
| Actual ...... | 7 | 8 | 2 | 8 | 3 | 1 |
| Vickers Hardness— As received.. | 171 | 193 | 151 | 137 | 110 | 123 |
| After stress relief at 650° C..... | 157 | 167 | 150 | 136 | 104 | 87 |

* No. 1–5 coarse, 5–8 fine, in McQuaid-Ehn test.
† Some isolated areas with grains > 1.

Eight specimen samples of each of the six steels as received were cleaned by grinding and finishing. All specimens were exposed to the atmosphere on the laboratory roof at Derby. At intervals a representative specimen of each steel was removed and examined, and the loss of weight determined after derusting. These corrosion tests showed, after 300 days, reductions in the rate of corrosion over that of a steel of ordinary quality, containing 0·09% copper, of 30% to 32% for additions of chromium, copper, phosphorus and silicon, 19% to 27% for additions of copper and chromium, and 12% to 14% for additions of copper with or without manganese. When the steels are painted there is little difference in the time taken for rust to appear, but the high-phosphorus steels appear to advantage after rusting has made some progress.

The small number of steels examined, and the considerable differences in analysis between them, make it rash to use these tests to single out any one element as beneficial or prejudicial to corrosion resistance. It is noted, however, that the general trend of the results accords with the published work, referred to by the author, on the beneficial effect of additions of copper and its enhancement by a high-phosphorus content.

Sheets having additions of copper with chromium, manganese or chromium, silicon and phosphorus all had good mechanical properties, the ductility of the steels with high contents of silicon and phosphorus being equal to that of the others. All showed a slight reduction in ductility, and an increase in hardness on ageing after strain, but in no case was this sufficiently marked to affect the practical usefulness. The greatest tensile strength was associated with the manganese addition, but considering both the mechanical properties and corrosion resistance, steels with additions of copper, chromium, phosphorus and silicon together seemed to be the most promising of the types tested.

Cupping tests seemed to be the most satisfactory method of following the course of ageing effects in sheet, although tensile test measurements gave corroboratory evidence. An attempt to produce the necessary strain with the Erichsen machine was reasonably successful, and thus the whole of the mechanical part of the test can be carried through with it if desired.

### The Thickness of Oxide Films on Iron

As a result of an investigation, described in this paper by Dr. H. A. Miley, M.A., new values have been obtained for the thickness of the oxide films responsible for the interference colours on iron by measuring the millicoulombs of electric current needed for their cathodic reduction. The apparent discrepancy between the gravimetric and optical results in the past has been explained as being due to the invisible oxide carried by the specimen at the time of the first weighing. The values obtained also agree well with chemical estimations of the thickness of the homogeneous films after removing them from the metallic basis. Thus, four methods have been brought into satisfactory agreement, and their differences explained by the fact that the different methods do not measure the same things.

Having ascertained the accuracy of the new method by comparison with others, it has been used to measure the rate of oxygen uptake at ordinary temperatures, and the results point to a rapid rate of exidation for a short time (influenced by temperature changes, effective area, and cracking of the film resulting from abrasion or other treatment), followed by a relatively slow rate of oxidation.

Vernon's observation[1] that no bright colours appeared on iron below 200° C.—even when the amount of oxidation was sufficient to have caused colours at higher temperature—was confirmed. The author believes that the oxide formed below 200° C. is $\gamma$-$Fe_2O_3$ (cubic structure), and the oxide formed above 200° C. is $\alpha$-$Fe_2O_3$ (hexagonal structure); if the $\gamma$-$Fe_2O_3$ is in optical continuity with the iron basis (cubic structure), it will afford no adequate lower reflecting surface, whereas, if the $\alpha$-$Fe_2O_3$ is crystallographically discontinuous with the basis it will provide the conditions necessary for interference.

### Roofing Sheets of Copper Steels and other Materials

A brief account is given in this paper by Sir Robert Hadfield and Mr. S. A. Main, B.Sc., of a series of practical trials of roofing sheets of special steels, conducted at the East Hecla Works of Messrs. Hadfield's, Ltd. The buildings at these works are mostly protected by steel roofing sheets, the average quantity of sheets required during the years 1920 to 1935 amounted to 84 tons per annum; the maximum in any one year was 145 tons.

1 *Transactions of the Faraday Society*, 1935, Vol. 31, p. 1,674.

The trials concern galvanised sheets, both painted and unpainted, of the following materials:

TABLE I.
Compositions of the Materials.

| Mark. | Type. | C. | Si. | S. | P. | Mn. | Cu. |
|---|---|---|---|---|---|---|---|
| | | % | % | % | % | % | % |
| | Copper-bearing steel— | | | | | | |
| 5551 | British | 0·05 | 0·06 | 0·027 | 0·041 | 0·52 | 0·35 |
| 5553 | American | 0·13 | 0·02 | 0·034 | 0·062 | 0·55 | 0·22 |
| 2239 | Ingot iron | 0·03 | 0·03 | 0·016 | 0·005 | 0·02 | <0·01 |
| 5554 | Ordinary roofing sheets | 0·07 | 0·03 | 0·022 | 0·051 | 0·33 | 0·022 |

The results of the trials as regards the corrosion of these steels, after a period of exposure of 9¾ years to date, show that only the unpainted sheets have given useful information so far. Copper-bearing steel is proving definitely superior to ordinary steel, but its merits did not appear until the galvanised coating had weathered off. The ingot iron tried has proved definitely inferior to ordinary steel. The relative life periods of the different materials will only be ascertainable after further exposure. Four locations of varying severity as regards corrosion give consistent information. Steel containing both copper (0·42%) and molybdenum (0·10%) is included in a further series of trials not yet sufficiently advanced for report.

The paper concludes with a commentary on the usefulness of practical trials of this nature, and the conditions necessary for their successful conduct.

### Alloy and Fine-Grained Steels for Locomotive Coupling Rods

Locomotive coupling and connecting rods are subject to buckling stresses from the piston, and to inertia effects when running at high speed. Slipping of the driving wheels imparts sudden dynamic stresses to coupling rods, and fatigue effects also arise. This paper, by Dr. Hugh O'Neill, M.Met., is not concerned with design, but engineers would probably agree that materials of high tenacity, combined with high resistance to fatigue, bending and shock are required. As regards the last point, the author assumes that a high Izod notched-bar value indicates good toughness properties and resistance to the propagation of incipient cracks.

The weight reduction of coupling rods has most satisfactorily been obtained by the employment of alloy steels, and the author discusses the mechanical properties of heat-treated nickel-chromium-molybdenum and manganese-molybdenum steels, the compositions of which are given in Table I. Certain unusual features infrequently observed in manganese-molybdenum steels are described.

TABLE I.
Tests in Oil-quenched and Tempered Condition.

| | Ni–Cr Steel. | | Ni–Cr–Mo Steel. | | Mn–Mo Steel. | |
|---|---|---|---|---|---|---|
| | Specification B.S. 38 11. | Example. | Block A. | Rod F. | Example, Rod 12. | Specification X. |
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Carbon % | 0·25–0·35 | 0·33 | 0·30 | 0·27 | 0·25 | 0·25 |
| Silicon % | 0·30 max. | 0·21 | 0·15 | 0·20 | 0·16 | — |
| Manganese % | 0·45–0·70 | 0·60 | 0·58 | 0·49 | 1·56 | 1·60 |
| Nickel % | 3–3·75 | 3·4 | 2·43 | 2·53 | (0·08) | — |
| Chromium % | 0·5–1·0 | 0·6 | 0·57 | 0·77 | (Trace) | — |
| Molybdenum % | 0·65 max.* | — | 0·68 | 0·34 | 0·30 | 0·25 |
| Sulphur % | 0·05 ,, | — | 0·033 | 0·006 | 0·012 | 0·04 max. |
| Phosphorus % | 0·05 ,, | — | 0·030 | 0·011 | 0·034 | 0·04 ,, |
| Yield point .. Tons/sq. in. | — | (Spec.) | 45·0 | — | 32·0 | — |
| Yield ratio % | — | 80 | 81 | — | 77 | 75 |
| Max. stress .. Tons/sq. in. | 55–60 | 50 | 55·8 | 66·5 | 41·5 | 40 min. |
| Elongation on 2 in. % | 18 min. | 18 | 25 | — | 27 | 20 ,, |
| Reduction of area % | 50 ,, | — | 63 | 54 | — | — |
| Izod value Ft./lb. | 40 ,, | — | 50 | 24 | 93 | 60 min. |
| Brinell number | 241–293 | — | — | 336 | — | — |

* Optional.

One of these features is banding, and another concerns variable values for the Izod impact tests. The view is expressed that, owing to local heterogeneity on perhaps only a microscopic scale, some portions of the steel enter the $A_1$ transformation interval during tempering, which

has been conducted at a nominally correct temperature. The result is to produce transformed structures giving impaired Izod values in the affected localities.

Manganese-molybdenum steels of controlled inherent fine-grain size have furnished uniformly satisfactory results. Particulars are given of plain carbon steels of inherent fine-grain size, which yield practically the same mechanical test values as low-alloy steels, and are giving satisfactory performance both during manufacture and in service as coupling rods. Their Izod notched-bar values are notably high.

Laboratory investigations of forgings from two commercial casts of fine- and coarse-grained plain carbon steel of a given composition suitable for coupling rods are described. The McQuaid-Ehn carburising test has been compared experimentally with various other methods of inherent grain-size determination. It was found to be satisfactory for differentiating these two casts of steel, though strain-hardened samples should be avoided. Methods involving a range of temperature are, however, perhaps more useful in general. A temperature-gradient chlorine-etching test has been developed for this purpose, which is rapid and suitable for laboratory purposes.

As regards depth of carburising and decarburising, flame-cutting, machining and cold-working properties, no important differences were observed between these fine- and coarse-grained qualities. The hardness gradients in oil-quenched blocks were similar. The coarse-grained steel hardened more intensely and more deeply on water-quenching, however, and was slightly harder after oil treatment.

The coarsening induced in both types of steel at 1,000° C. is removed by subsequent heat-treatment; but in one test, made after soaking at 1,230° C. for 4 hrs., the fine-grained steel was not fully restored to its normal Izod value. Very high-process temperatures of this order should therefore be avoided if very high Izod values are finally desired.

Actual physical grain size *per se* is not considered to be the prime cause of the great differences in Izod value observed in the two types of steel.

## Morphology of the Inclusions in Siderurgigal Products

In Parts I and II[1] of the investigation on the above subject, Prof. A. M. Portevin and M. René Castro described the morphological aspect of inclusions in iron and ordinary steels, in the presence of manganese, silicon and aluminium on the one hand, and of sulphur and oxygen on the other. Part III[2] related to inclusions met with in industrial steels and alloys containing chromium in addition to the elements mentioned above. The present paper incorporates Parts IV and V, the former describes and illustrates the inclusions characteristic of the presence of titanium, zirconium, and vanadium, while the last part of the research, Part V, illustrates the classic types of inclusions containing these elements, besides describing other types which are less known but nevertheless typical.

1 Part I, Introduction; Part II, Iron, Steels and Alloys not containing Special Elements. *Journal of the Iron and Steel Institute*, 1935, No. II, pp. 237–274.
2 Part III, Chromium Alloys and Chromium Steels. *Journal of the Iron and Steel Institute*, 1936, No. II, pp. 213P–239P.

# The Heterogeneity of Steel Ingots

*The Seventh Report by a Joint Committee of the Iron and Steel Institute, and the British Iron and Steel Industrial Research Council.*

WORK on the heterogeneity of steel ingots by this Joint Committee has now been in progress over eleven years, and several reports have been published. The work of the Committee is still continuing, and further work in this, the Seventh Report, was presented at the meeting to enable certain aspects of the subject to receive the consideration of the members of the Institute for the purpose of constructive discussion.

The Report is given in seven sections, the first of which reviews the work already done, the object being to assist in directing thought, and perhaps experiment, to certain outstanding difficulties which as yet remain to be dealt with before an adequate picture can be obtained of the mechanism of the freezing of killed steel into the form of the crystal aggregate which constitute the ultimate ingot. It is prepared to focus anew the nature of the complex of problems still awaiting solution.

The Committee have carried out extensive examination of ingots, and are now in a stronger position when considering the problem of heterogeneity. This is largely because the form of the internal structure, typical of each commercial type of ingot, has been determined, and data have been obtained on a number of the more fundamental aspects of the subject. The work published in earlier reports is briefly reviewed, and attention directed to the more-important pictures. New work is discussed in the remaining sections of this Report, to which only brief reference can be made here.

### Rimming Steel

The results of a very valuable research, conducted by Dr. T. Swinden on a basic Bessemer rimming steel ingot, is presented in Section II. Consideration of the theories underlying the phenomenon of rimming indicates the desirability of more precise information concerning the variation in composition from the outside to the centre of the ingot of rimming steel, not only in order to study the characteristics of the material, but as a basis for a hypothesis in explanation of the rimming phenomenon. With the object of providing these data, a detailed examination has been made of (*a*) a billet of open-hearth rimming steel, containing 0·16% carbon, and (*b*) an ingot of basic Bessemer steel, details of which are given in the Sixth Report.

The results of the latter are particularly interesting. They show that as regards carbon, sulphur and phosphorus, there is a definite fall as one traverses from the outside of the ingot through the rim. At the junction of the rim and the core there is a sudden rise to a peak, which is well above the average composition of the steel, following which there is a flattened curve with a secondary peak. In the case of manganese there is a small but definite reduction in the content through the rim, followed by a rise at the junction of the rim and the core, beyond which the manganese content is fairly constant.

The distribution of the elements has been determined in a meticulous manner not previously attempted, and the results, while implementing and extending knowledge of rimming steel, have also a much wider bearing on the general subject of heterogeneity. For instance, it is now definitely experimentally established that manganese and sulphur do not segregate together. Attention is particularly directed to Fig. 4, in the compositions are correlated with the sulphur print.

It is the author's intention to carry this investigation further by examining the oxygen values as thoroughly as methods of determination will permit, though a similar zone of the data presented are included; but it is desirable to await the oxygen values as thoroughly as methods of determination will permit, through a similar zone of the same ingot. Some observations on the theory in explanation of the data presented are included, but it is desirable to

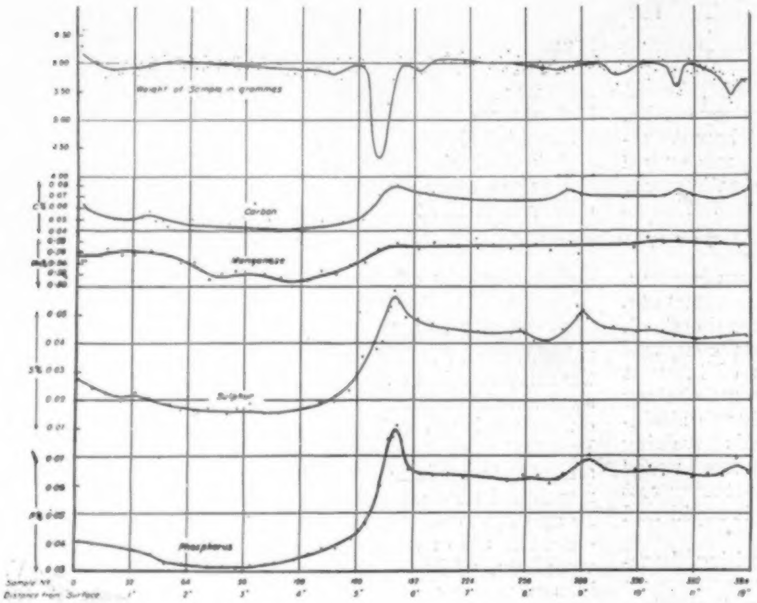



*Fig. 4—Variation of carbon, manganese, sulphur and phosphorus in a rimming steel ingot. Scale ½ full size.*

areas rich in manganese sulphide, a feature which has hitherto remained unexplained.

In the second contribution in this Section, Dr. T. Raine, B.Met., and Mr. J. B. Vickers, M.Met., under the direction of Professor Dr. J. H. Andrew, give the results of the determination, by both the alcoholic iodine extraction method and the vacuum fusion method, of the oxygen content in the various samples studied by Mr. Whiteley. This paper is particularly interesting, as being the first contribution containing oxygen determinations in accordance with the approved procedures agreed as a result of the collaboration with the Oxygen Sub-Committee, whose report is given in the next Section.

### Determination of Oxygen in Steel

In Section IV of this Report of the parent Committee is given the first report of the Oxygen Sub-Committee. As far back as 1932 the non-metallic inclusion content of ingot samples had been quantitatively examined and reported by the Committee. Since that time new methods have been introduced, and this Section contains a description of the first attempts at a complete and systematic study of the methods of determination themselves, with a view to their development and co-ordination.

The work has been carried out at the National Physical Laboratory, Sheffield University, the Central Research Department of the United Steel Companies, Ltd., and, since October, 1936, the Research Department of Imperial Chemical Industries (Alkali), Ltd., and the following methods are described: the vacuum fusion method, the alcoholic-iodine method, and the chlorine method.

The importance of this work cannot be over-estimated. Work on the oxygen content of different steels has, in the the past, been published, the value of which has been seriously limited by the possibility of wide error in the methods of estimation employed; and despite all attempts at making suitable allowance for these errors, when they were known, the conclusions themselves have often rested upon an insecure foundation.

The Sub-Committee, therefore, has as its first object the complete correlation and examination of all practicable methods of oxygen determination, with a view to making them available to properly equipped laboratories.

In this respect the Sub-Committee considers that sufficient progress has been made to undertake, with reasonable satisfaction, the determination of oxygen in samples representative of different types of steel in different stages of deoxidation. Notwithstanding this progress, which, in view of the wide discrepancies which have recently been published from several sources (the Committee's own work not excluded), must be considered extremely satisfactory, the Sub-Committee proposes to pursue its work of a more fundamental nature with a view to evolving simpler and cheaper equipment, and more rapid and simpler chemical methods of evaluating the oxygen present in inclusions.

### Gases in Iron and Steel

The results of some further experiments on gases in iron and steel, and their effect on the solidification of the ingots, are given in a communication by Dr. T. Swinden and Mr. W. W. Stevenson, A.I.C., in Section V. The work reported in Section VIII of the Sixth Report has been amplified. Argon has been used in a manner similar to that employed for other gases in the previous Report; it is shown that argon has no tendency to produce unsoundness when passed through liquid steel, and, moreover, that it removes the unsoundness effect otherwise produced by a

(Continued on page 32.)

await the oxygen data before the hypothesis outlined can be regarded as other than tentative.

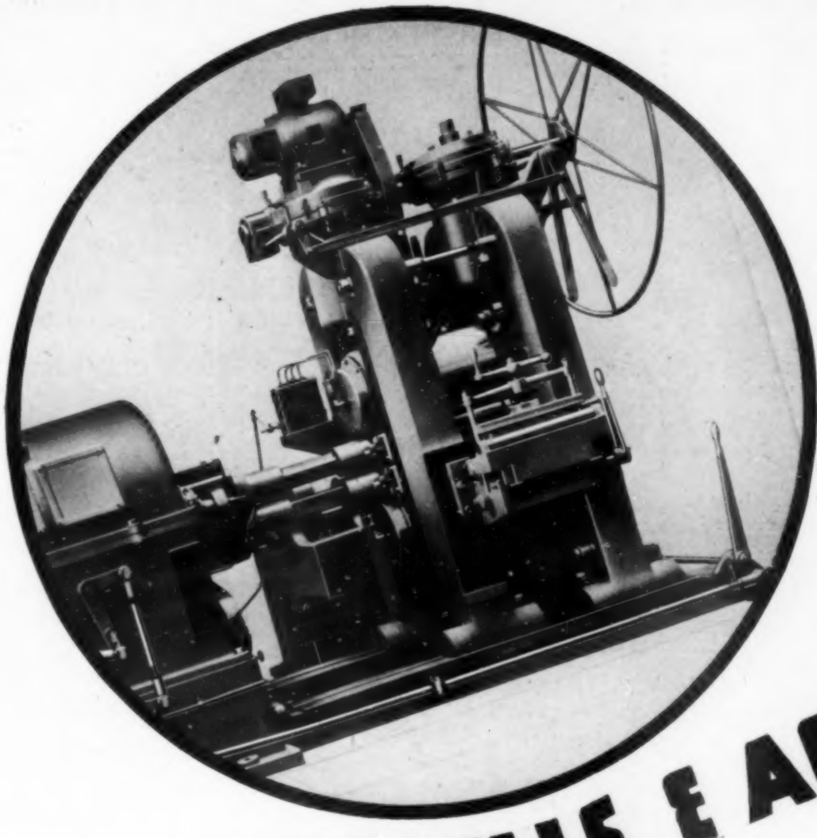
### Non-metallic Inclusions

An interesting treatment of the non-metallic inclusion content of an electric-arc-furnace cast of steel is given in Section III. The examination concerned the inclusion contents of a series of bath samples from an 8-ton experimental cast of 0·55% carbon steel.

In the first contribution in this Section, Mr. J. H Whiteley, F.I.C., deals with the nature and characteristics of the inclusions and the sulphides in this cast. Samples were taken from the furnace for the purpose of determining the oxygen content of the bath under the changing conditions of working. Most of the metal samples were in duplicate, one being allowed to set undisturbed, and the other being killed in the spoon with aluminium. Details of the charge history and analyses of both slag and metal samples are presented.

The author describes a preliminary investigation in which a thorough examination of the non-metallic inclusion was made. In the unkilled series four types could be distinguished—viz., sulphides, silica and silicates, opide and slag. Methods used for identification are given. By means of a counting method the gradual increase of oxygen in the metal as the boil proceeded, and its subsequent steady removal in the refining period, are demonstrated. In the killed samples the inclusions were chiefly sulphides and aluminous material, and although the counting method was there inapplicable, the same oxygen changes were manifest when the visible quantities of aluminous inclusions were compared.

It is also shown that unkilled samples are quite unsuitable for estimating the oxygen in the bath, since they may be contaminated with slag particles derived in sampling, and with oxide films due to air penetration. In this respect aluminium-killed samples are much more satisfactory; but even so, a method of obtaining fully reliable samples has probably yet to be devised. A minute but remarkable segregation effect, containing apparently massive carbide, is described. Lastly, the sulphides are studied. As a result it is shown that much of the sulphur in ordinary steels solidifies as iron sulphide, which changes later to manganese sulphide in the solid steel. This fact throws light on the frequent deficiency of manganese in segregated



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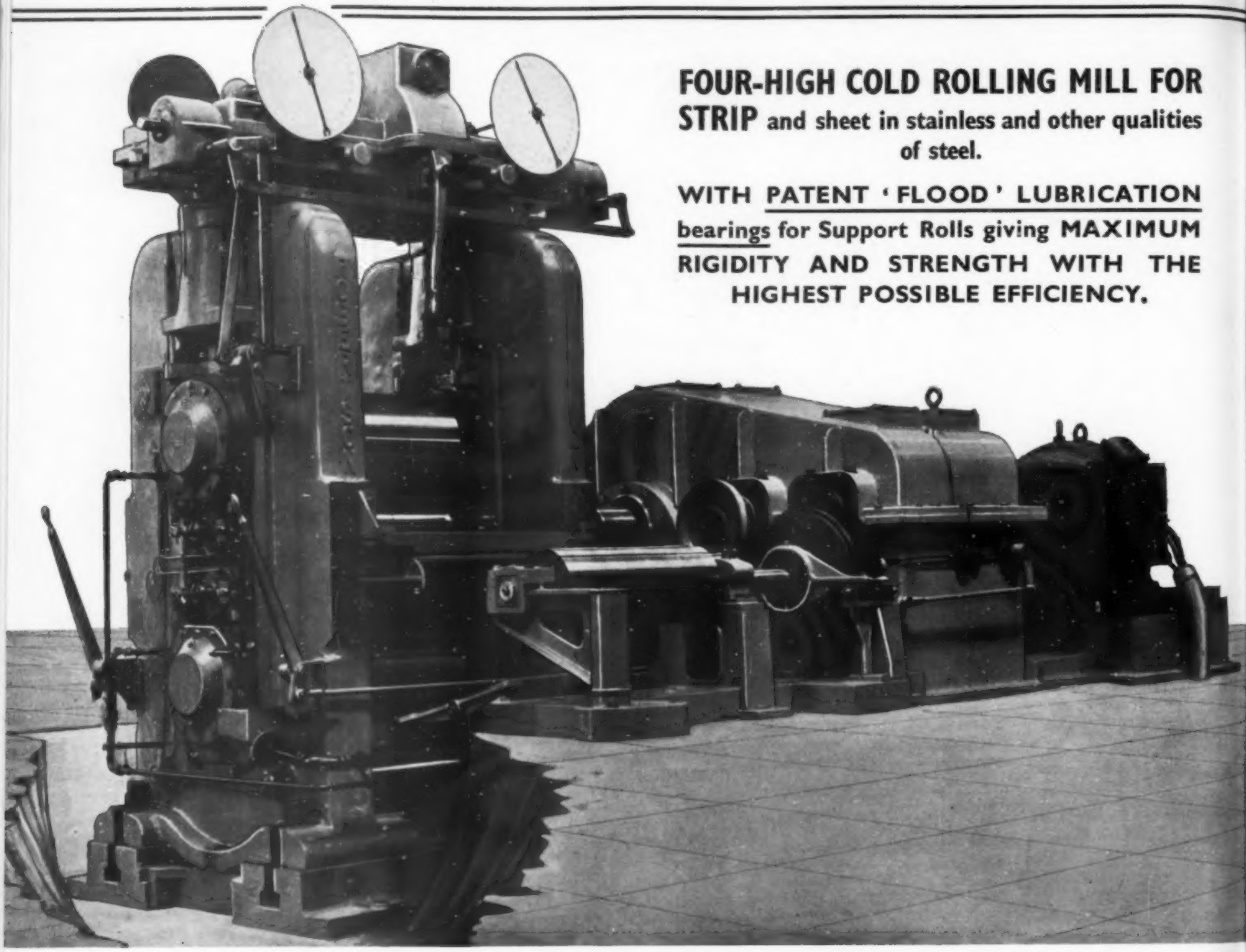

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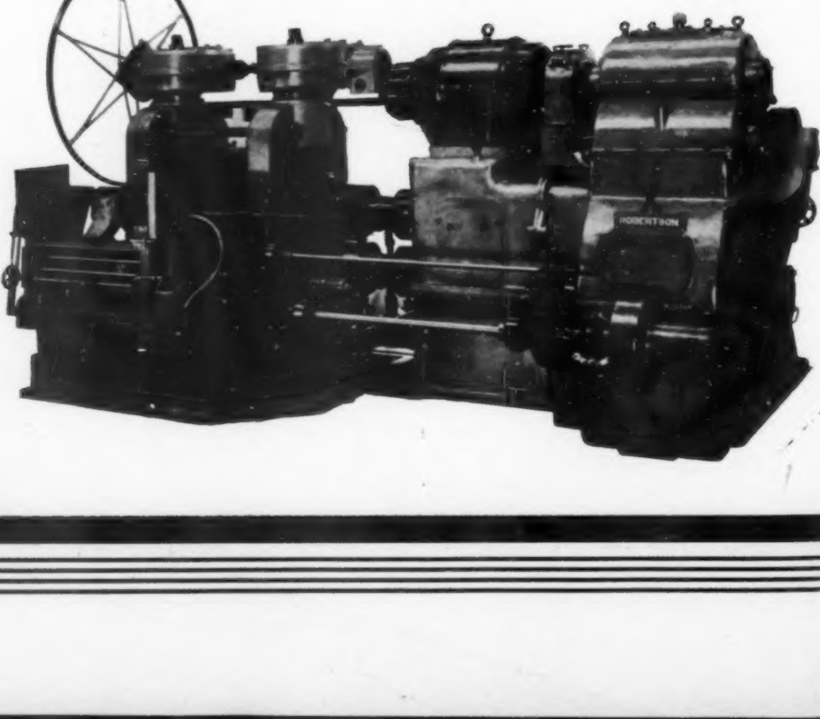


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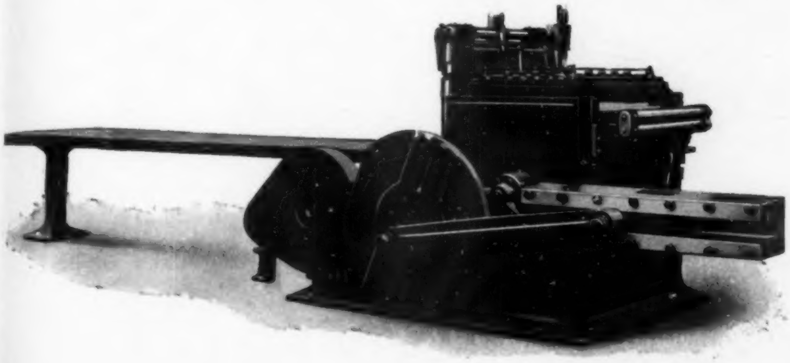

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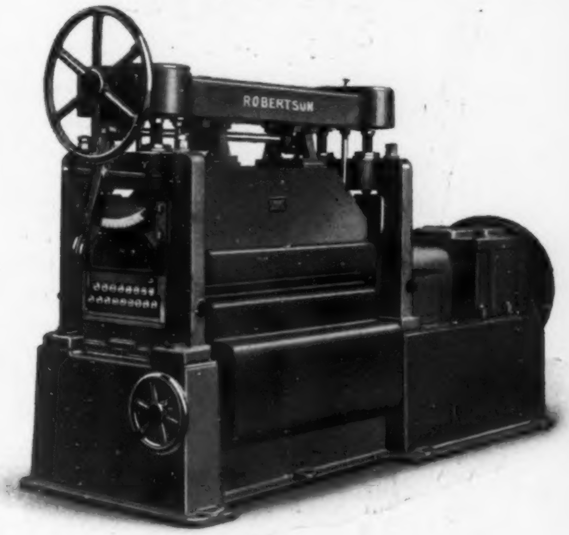


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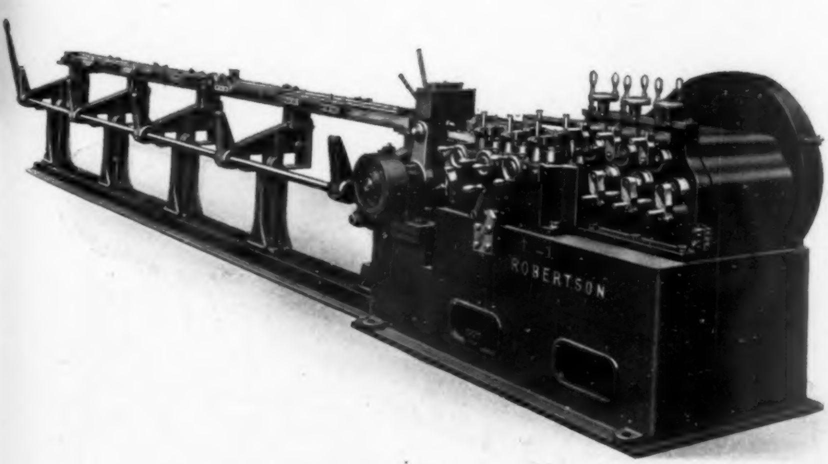


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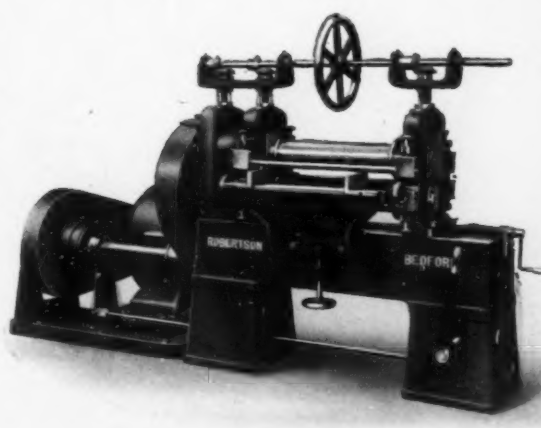


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# Steel Pickle-Brittleness

By RICHARD SAXTON

*Many qualities of carbon steel are susceptible to attack by new pickling solutions which penetrate the surface pores of the metal, and impart a condition of severe pickle-brittleness where immersion is prolonged due to the resistance of the scale to chemical action. Some of the difficulties are discussed in this article.*

THE process of pickling or acid-cleaning steels, whilst not the ideal method, and certainly more detrimental to quality than otherwise, is still the most economical and practical for the efficient removal of oxides from the metal. Latterly, this method has been the subject of much experiment *re* operating as a continuous process, and though successful with bright and semi-bright material, the variation in scale formation, with qualities necessitating hot working, has so far rendered the adaptation to steels fabricated in this way a matter of difficulty.

The chief acids employed in steel pickling are hydrochloric, sulphuric, nitric and hydrofluoric. Commercial hydrochloric has the widest application, particularly in the cleaning of carbon qualities, sulphuric being employed chiefly in processing alloy steels. Nitric, due to keen penetrative action and cost, is rarely employed for carbon steel processing, but in conjunction with sulphuric is found of service in pickling stainless qualities.

Hydrofluoric is only employed in special cases where the use of the three previously mentioned acids fails to achieve the purpose. It has, however, a wide use in the removal of oxides from castings, as silica the main constituent of foundry sand is impervious to sulphuric or hydrochloric attack.

Hydrochloric solutions, due to their property of functioning at atmospheric temperature, have their widest application in the cleaning of carbon steels processed for cold deformation work, as in the fabrication of wire or drawn bars. Employing new acid, these solutions possess keen penetrative action in contact with carbon steels, penetrating the surface pores of the metal and imparting a condition of severe pickle-brittleness where it is necessary to prolong the immersion due to resistance of scale to chemical action.

The susceptibility to pickle-brittleness of many carbon qualities in contact with hydrochloric solutions is a frequent source of trouble in later processing, and as a preventitive the use of inhibitors or restrainers has been advocated, but objection to their employment is found in many quarters on the ground that inclusion of these compounds slows up production. The action of these additions chemically has never been definitely proved, but general assumption is that when a clean surface is exposed the inhibitor and metallic constituents of the material combine to form a protective film preventing further attack.

Contrary to the general assumption, there is little solvent action on oxide formation, this latter being porous permitting easy percolation to the metallic base, the contact resulting in the evolution of hydrogen, and this in turn forcing away the oxide from the metal. Due to the affinity of steel for hydrogen much of the latter is absorbed by the metal, resulting in an extremely brittle condition unless eliminated by subsequent processing.

Pickle-brittleness and acid rust are unavoidable defects imparted by acid immersion, and though various methods are employed to eliminate them the most thorough is to evaporate by application of dry heat at 200° C. Pickle-brittleness is due to hydrogen percolation of structure, the resultant effect being an unstable condition of grain structure. Acid rust is a corrosion defect affecting chiefly the grain boundaries and resulting, where unchecked, in total disintegration of the structure.

The detection of pickle-brittleness prior to further operations is a difficult matter, the only change noticeable being a slightly darker cast. Acid rust, in general the result of inefficient neutralising, cannot be detected and, where present, is usually revealed later by the formation of a thin film of surface rust, this forming in many cases after the material has been worked into the finished product.

Hydrochloric solutions can be employed heated as well as cold, but trouble with the former is that attack with many qualities is too rapid ; the acid penetrating deeply before the scale is removed. Heating weak solutions prior to running off is good practice and furnishes higher production than is possible working at atmospheric temperature until completely spent.

Sulphuric solutions require the application of heat to function efficiently, and the rate of attack varies with the strength of the solution and the temperature to which it is raised. The higher the temperature the more rapid the action, and whilst susceptibility to acid rust is less with sulphuric treated steels, impairment by acid percolation is greater. Most economical solution for general work is a 5% sulphuric at 60° to 80° C., this furnishing a higher output with less risk of acid defects that is possible with other solutions or temperatures.

In sulphuric pickling there is a point at which, due to accumulation of iron sulphate, further additions of acid serve no useful purpose. It is economic procedure when the solution has reached this stage to pass through a strainer, the liquor recovered being retained for addition to new baths, as it is useful for restraining the too rapid attack of new acid.

In sheet pickling the employment of the sulphuric process is practically universal. The solutions employed vary from 5% to 10% acid, and are worked at a temperature of approximately 90° C., which gives an immersion time for sheets in fair condition of about 4 mins. For machine pickling, which has the necessary equipment to maintain the solution at a fixed strength, the immersion period as given is reduced 25%. General practice with tinplate sheets is to follow pickling with a close annealing treatment which, in addition to rendering them more pliable, drives off any hydrogen remaining. The bluish sheen formed on sheets on unloading after annealing is removed by a dip in weak acid.

Trouble encountered in sheet pickling is the formation of rust marks on the completion of the operation, due to inefficient elimination of acid. General practice of immersing or washing in cold water has little effect in dispersing any but surface acid, and the acid carried over into the alkali neutralising solution being a compound of iron salts and free acid reacts with the alkali to form chemical compounds which adhere to the sheet in the form of detrimental stains.

Efficient pickling of stainless steels requires a knowledge of the reaction of the particular quality to acid immersion, as these metals vary widely in analysis. In pickling austenitic qualities there is the choice of two processes and probably the most widely employed and acknowledged safest is the two-bath method, in which the material is first immersed in a sulphuric solution followed by a nitric bath employed cold.

The action of the sulphuric mixture loosens the scale

only and attack on the metal by nitric is practically nil, but care must be exercised against too long immersion, or a black scum is formed on the metal extremely difficult to remove. Austenitic stainless steels are extremely susceptible to pickle-brittleness in the annealed condition, and with qualities with which reaction to acid is unknown it is wise practice to first test sample piece.

An alternative method is a one-bath process employing a 20% hydrochloric, 5% nitric solution. The advantage of this bath is that oxides are removed in one operation, but the risk of imparting acid defects is considerably greater, as these steels are extremely susceptible to hydrochloric attack. The addition of sodium chloride to the sulphuric bath is found beneficial in treating certain qualities ; speeding up attack without increasing susceptibility to acid defects.

In the cleaning of steel castings sand blasting is gradually being superseded by the acid immersion process as a more economic proposition. One drawback to wider employment is the porous nature of the metal in cast form when exposed to acid contact, and risk of pickle-brittleness is greater in this condition than when worked hardened. A further detriment, often resulting in prolonged immersion, is the silica baked to the metal by the fusing of the sand.

General practice in acid casting cleaning is to first immerse in sulphuric solution to remove bulk of sand and scale, then finish off with 10% hydrofluoric. Hydrofluoric solutions are practically the only compounds which will remove silica fused to the metal, and, as their employment is dangerous in inexperienced hands, care should be exercised both in preparation and process. To neutralise acid remaining after washing, castings are immersed in hot sodium carbonate or trisodium phosphate solutions which, if heated sufficiently, dry off and leave a deposit which acts as a protection against corrosion. Withdrawal of casting from the bath slightly heated also facilitates the evaporation of hydrogen absorbed.

The increasing employment of alloy steels in strip form has led to the introduction of continuous processes for acid pickling these particular qualities, and though highly efficient in the treatment of material with only a thin oxide or film deposit, results with the heavier scaled hot-worked material have not been the success anticipated.

Due to larger volume of acid essential for efficient pickling these processes are only economical where the output is such as to ensure being fully engaged, any stoppage or intermittent employment leading to loss by evaporation and weakening of the solution with greater area exposed to the air. Immersion time is little decreased by the employment of these processes, but with acid functioning efficiently and no material required to be returned for a second immersion output greatly exceeds equal plant employing the older bath method.

The introduction of the continuous process has been followed by many improvements, not the least of which is a cleaner atmosphere in the department. Fumes generated are confined in this process by suitable covers in which ducts are incorporated to draw off and convey to a water-spray tank. In the older method little provision is made to cope with fumes apart from curtailment by suitable inhibitors, whilst the use of covers as described is hardly a practicable proposition.

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Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness, Lancashire, have sent us a booklet entitled "Barrow Steel: a Brief History and Survey of Productions." It presents an interesting story of the early history of ironmaking on the North-West Coast, including the history of pioneer works, and ends with an informative survey of the Barrow Steel Co. to-day It is admirably presented and produced, the illustrations in particular being excellent. This is a very readable book to all interested in the iron and steel industry of this country, and one which is likely to be preserved. We understand copies are available gratis on application to Barrow Hæmatite Steel Co., Ltd.

# The Flow of Metals

THE twenty-seventh Annual May Lecture recently delivered before the Institute of Metals by Professor E. N. da C. Andrade, D.Sc., Ph.D., F.R.S. in the Hall of the Institution of Mechanical Engineers, London, dealt with the flow of metals. Flow is most easily observed in the liquid state, but whereas there is a satisfactory theory of gases, and the structure of crystalline solids has been elucidated by the methods of X-ray analysis, very little is known of the actual behaviour of the molecules in the liquid state. It lacks the regularity of the crystal, and the molecules are too close to show the simplicity of behaviour that characterises gases. A liquid has about the same density as a solid, and can be regarded as a solid in which the heat agitation leads to a slow movement of the molecules from their places, a molecule travelling through a distance equal to its diameter after something less than, but approaching a hundred impacts.

Andrade has put forward a theory of liquid viscosity on the basis that the momentum is transmitted from layer to layer, not, as in a gas, by the passage of molecules from one layer into the other, but by instantaneous association of the molecules when they touch, so that at any nearest approach two molecules share their momentum. On this basis a formula can be derived which gives the viscosity of a simple liquid at its melting point, and another which gives the temperature variation of the viscosity.

Molten metals are particularly suitable for experiments designed to throw light on this problem of viscosity, because they constitute liquids which consist of one kind of atom only, and they are not, in general, associated. The viscosity is conveniently measured by sealing up the molten metal in a sphere, suspended *in vacuo*, and observing the damping of the torsional oscillations of the sphere about a vertical axis due to the enclosed liquid. The method has already been used for the alkali metals, and is being extended to other metals.

The flow of solids, is perhaps, at first sight, even more troublesome theoretically than the flow of liquids, for single crystals of metals exhibit plastic flow under very small stresses, whereas a perfect crystal should firstly be strong, and secondly be brittle. Again, single crystals of metals show a very marked hardening with flow. The mechanical properties of metal crystals have been elucidated by the work of Polanyi, Schmid, G. I. Taylor and others, and it is now known that the factor which initiates plastic flow is the shear stress in a certain crystal plane and in a certain crystal direction, which can be found by experiment, but there is no general rule, applicable to all crystals, which enables us to decide beforehand what the plane will be, whereas the direction is always the direction in which the atoms are packed most closely. The glide direction seems to be more significant and fundamental than the glide plane.

To explain how it is that metal crystals can flow at all, various workers have suggested, with different detail, that, in the ordinary crystal, places exist where the atoms are out of step, for a small distance, with their immediate neighbours, such regions being called "dislocations" by Taylor. It can be shown that quite a small shear stress will cause such a dislocation to run along, leaving the atoms in the region through which it passes advanced by one. The weakness and the flow of single crystals is explained along these lines. Other internal flaws have been involved to explain the time factor in the flow, and the hardening. It cannot be said that there is any fully satisfactory theory of the flow of single crystals of metals, but a good beginning has been made.

It is, of course, a far step from the single metal crystal to the polycrystalline metal of industry, but we can see that any crystal boundary is likely to stop the propagation of a dislocation, or glide in general, and so will make the metal less weak and less liable to flow. Industry cannot, of course, wait for theory, but the only really satisfactory way to approach the problem of the strength of metals is by way of the single crystal.

# Free-Cutting Light Alloys

*Germany is making great efforts to render herself completely independent on non-domestic materials, and special interest is attached to the development of light alloys for free-machining. A symposium on this subject was recently held under the auspices of the Aluminium Zentrale (the central information and development organisation of the industry) in Aachen, and the following review of the subject is based on the papers and discussion presented at that symposium.*

IT has, up till recently, been generally accepted that aluminium and aluminium alloys require different tools for machining from those employed for steel or the copper alloys. Good results have admittedly been obtained with light alloys by the use of properly-designed tools, and by using special cutting angles differing from those used with heavy metals and differing also among the individual light alloys. The opposition which has been made to the use of light metals in the automatic machining industry, which in the past has principally utilised free-cutting brasses, is therefore readily understood. It has not been an economical proposition to provide both expensive tools and a special battery of machines to work with a new material for which entirely new conditions apply, and for which accumulated experience is valueless.

It is generally known that when light metal is worked in a machine it gives rise to long turnings which, besides the disadvantages associated with long and tough turnings from the point of view of actual machining, present a definite danger both to the machine and to the operator. As a rule, these conditions may be somewhat improved by cold-drawing the material after annealing and before machining : this has the effect of producing shorter and less tough chips. Incidentally, this goes to show that there is a relationship between the length of chip and the ductility of the material.

Where long turnings are formed it is necessary to remove them continuously, an operation which can only be performed by hand, and involves frequent injury to the operator's hands, even when gloves are worn, frequent injury to the surface of the material being machined, a considerable slowing-up of the machine output with consequent increase in operating costs and the necessity for providing means for removing, storing and ultimately cutting up the turnings. Quite apart from these facts, the subsequent working and remelting of the turnings and chips are both costly and difficult.

Since no satisfactory solution of the problems of machining light metals has been found by the machining industry, working in conjunction with the suppliers of the material, it is perhaps understandable that the light metal industry has rested content with the dictum of the machining industry and has, until recently, made no attempt to develop free-cutting light alloys which would be effectively independent of the tools and machining conditions employed and would possess, as far as possible, machining properties equivalent to those of brass. This lack of development in the aluminium industry has not been restricted to any one country, but has applied in all the countries which have fostered the industry.

Another factor which has had an important influence in this lack of development—and may, in fact, have been the most decisive—is the unfavourable price comparison between aluminium and the light aluminium alloys and brass, which has made it impossible for the former to compete on an economic basis with the free-cutting brasses.

In Germany, however, as things are to-day, there is a strong drive to develop home-produced materials in all directions, and consequently—as aluminium is a German domestic material and figures large on the horizon—research has been focused upon the development of free-machining alloys of aluminium base which could replace brass and could be worked with the standard machine tools.

When embarking on the development of such alloys, a careful survey was made of the technology of the free-cutting steels and brasses. In both these materials successful results have been achieved by the addition of alloying constituents possessed only of limited solubility in the basis metal both in the solid and in the liquid states. In the case of brass, for instance, lead is such a constituent. In the case of steel, also, free-cutting properties have been achieved by the incorporation of slag components such as sulphides or silicates or even oxides. In alloy steels such as chromium steel compounds, such as complex iron-chromium carbides, are probably formed in addition to sulphides.

The valuable alloying elements for the production of free-machining properties are in fact such as on the one

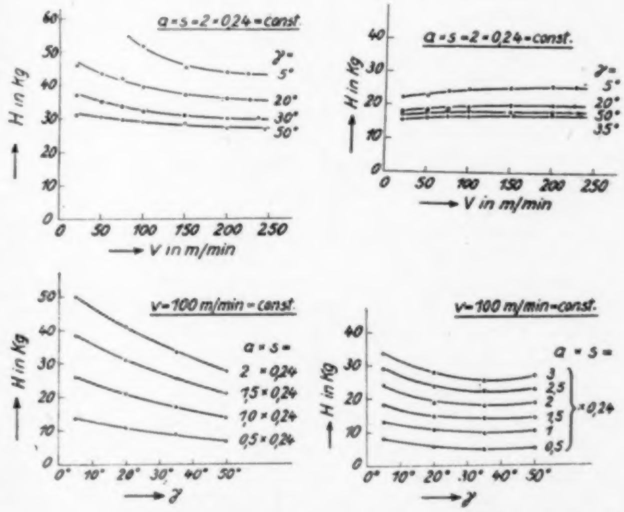



*Fig. 1.—Influence of the cutting speed* V *and top front rake angle* γ *on the cutting power* H *in two different light alloys.*

hand give soft, low-melting point compounds, and on the other hand, brittle constituents.

As far back as 1931, Hansen and Blumenthal showed that additions of lead to pure aluminium produced a shortening of the chips when the metal was turned. Quite recently, alloys of the aluminium-copper-magnesium type have been put on the market, first in America and shortly afterwards in Germany, for free-machining ; these alloys have contained additions possessed of limited solubility such as lead, bismuth and cadmium. Still further improvement in the shortness of the chips or turnings may be induced in alloys with these constituents by special heat-treatment, which has, however, the disadvantage of markedly affecting the corrosion-resistance, or by cold-drawing.

Lead has definite disadvantages as an alloying constituent to alloys of aluminium base. In the first place, in the production of such alloys segregation is difficult to

prevent : and anything approaching uniform distribution of the added lead can only be achieved in small melts and by some measure of over-heating or by the use of special production conditions. The production of semi-manufactures from ingot is also attended by special difficulties to prevent local concentrations of lead which would induce local cracking under stress. There is the disadvantage associated with the utilisation of any chips or turnings of such alloys containing lead for remelting with other material—special objections attach to the admission of such waste material to the scrap market. There are also certain problems connected with the properties of the lead-containing alloys—for example, the difficulty of treating them by the anodic oxidation processes and the unreliability of anodic coatings which may be produced.

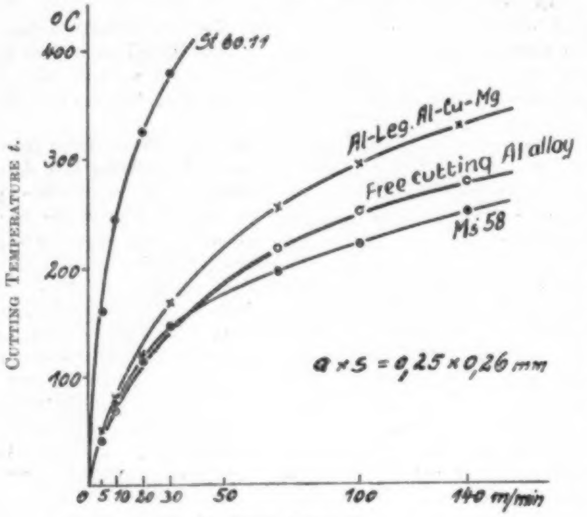



*Fig. 2.*

From the point of view of free-machining properties, however, lead has been definitely found of value ; and the reasons for this are of material interest. Schallbroch has shown that the temperature at the cut edges of the free-cutting brasses containing lead are in the region of 250°, whilst with the free-cutting light alloys the temperatures are of the order of 300° and over. When it is considered that to produce this temperature at the cut edge the material as a whole must be at a considerably higher temperature, it is clear that the melting-point of lead is with certainty exceeded : the shortening of the chips being due to the melting of this constituent at the grain boundaries. In those cases where the melting-point of lead is not reached, the small tensile strength of the "embedded" lead is in itself sufficient to bring about rupture, i.e. the chip-shortening property thus the desirable free-cutting properties are obtained at the expense of the tensile strength of the material.

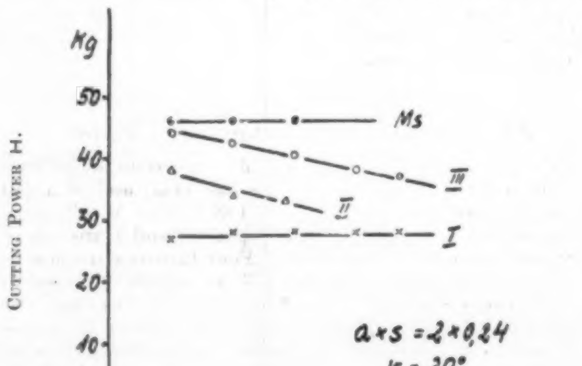
Other alloying elements such as tin, cadmium, bismuth and antimony which again form with aluminium or with the aluminium-magnesium alloys completely insolubie or only slightly soluble constituents consisting either of pure metal or of intermetallic compounds also suffer from some of the same disadvantages—particularly that of adding such elements as true alloying constituents.

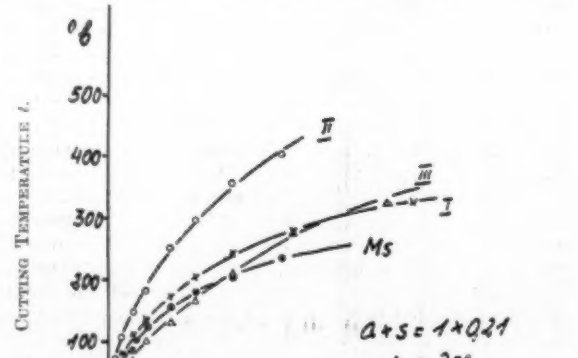
The alternative method of producing a free-machining material by addition of alloying elements which give rise to components which are more brittle and, among other things, harder than the matrix metal, by analogy with the free-machining steels, was therefore worth exploration.

Whilst, in the majority of alloys in the wrought condition the nature of the precipitated intermetallic compounds is similar to that of the same compounds in the cast condition, this is not the case with the aluminium-magnesium alloys. In these alloys the compound $Al_3Mg_2$ precipitates out from the solid solution in an extremely finely-dispersed condition either at the grain boundaries or in the grain itself, or in some cases both at the grain boundaries and in the grain ; whilst in certain cases no grain boundaries may be discernible. The very fact of the heterogeneity accounts to a certain extent for a measure of chip-shortening—which may not, however, be adequate for automatic machining. If, on the other hand, the heterogeneity is too marked, the alloys suffer from considerable reduction in elongation and impact notch toughness which renders the material unsuited to many applications.

It has, however, been found that certain further alloying additions such as manganese, iron, chromium, vanadium, titanium, molybdenum, etc., when added in quantities to give rise to hard intermetallic compounds in aluminium-magnesium-base alloys (the content being small, of the order of 0·75%), impart a very considerable degree of free-cutting properties by virtue of these hard aluminides. The alloys at the same time conserve their normal heat-treatment and mechanical characteristics ; they also exhibit all the differences ordinarily observed as between the homogeneous and heterogeneous states in the straight binary alloys, the finely distributed compound $Al_3Mg_2$ being in the same way responsible for the production of short-chip qualities. The higher the magnesium content of the alloys, the shorter in general are the turnings.

The aluminides present in such alloys are appreciably harder than the matrix metal. Alloys with only one aluminide-forming constituent, however, suffer from a number of disadvantages : they do not give very clean




*Figs. 3a and 3b.—Cutting power and cutting temperature for three light alloys and brass.*

machined surfaces, as the aluminides are coarse-crystalline, and account for a considerable cross-sectional area of the material : when subjected to corrosive conditions or submitted to anodic oxidation preferential dissolution, with all its attendant disadvantages, arises : and the structure tends to be "spongy," which gives rise to trouble in pressing, extrusion and other working operations. Research was then made on the alloys with more than one aluminide-forming constituent since it was believed that the primary magnitude of the complex aluminides is smaller than that of the ternary or even quaternary compounds. Investigations have shown that some of these complex aluminides enter into peritectic reactions with the aluminium-magnesium solid solution or with the compound $Al_3Mg_2$. These reactions can take place in the ingot, and can be induced by controlled heat-treatment : they can also be made to occur by a suitable choice of composition during the ordinary course of solidification of the ingot. Heat-treatment is, however, necessary in wrought materials—at any rate, to complete the reaction.

The aluminides have, however, rather a strong tendency to segregate in the molten condition, and it is not invariably possible, and is nearly always difficult, to arrive at a uniform distribution of these compounds—with consequent fluctuation of the mechanical and other properties of the alloys containing them : the cost of heat-treatment to induce or complete the peritectic reaction is also a factor weighing against the adoption of these alloys. Attention was therefore next turned to alloys containing a higher silicon content than that normally found in the magnesium-containing aluminium alloys (4—14% Mg) : the poor surface finish obtainable with these alloys with added silicon unsuits them for machining purposes, however, in spite of their improved short-chip properties. It was then discovered that part of the silicon could be replaced by manganese without detrimental effect to the short-chip properties and with a more highly dispersed condition of the intermetallic compounds, which occur in plate-like form. These alloys with silicon and manganese met many of the requirements for free-machining materials, but had disadvantages associated with their rather poor corrosion-resistance : the next step was to remedy this. It was known that in alloys of the Hydronalium type the presence of zinc improves the corrosion properties and accordingly investigations were carried out to determine the effect of adding zinc to the new series of alloys. It was found that the corrosion-controlling properties of the zinc additions were unaffected by the presence of the alloying constituents added to give the desired free-cutting qualities. It was also found, unexpectedly, that the zinc additions had the further property of reducing the size of the deposits of silicides or aluminides, either as primary precipitates in the melt or after mechanical deformation of the ingot.

No very narrow limits are imposed for the permissible range of the zinc additions in so far as these affect the favourable properties which this element contributes.

The scrap from the alloys does not vary so far from the ordinary composition of Hydronalium that small quantities are likely to have a dangerous effect on re-melt metals in which it may be incorporated—at any rate the scrap cannot be regarded as so undesirable as the scrap containing lead from the aluminium-copper free-cutting series.

The chips obtained from the new Hydronalium DBA alloy in its final form are extremely short, and the alloy compares well in this respect with free-machining brass : in fact, the somewhat longer turnings as compared with brass which may form in some operations are not to be regarded as wholly undesirable, since too short chips interfere with proper lubrication. In contradistinction to the aluminium-magnesium-complex aluminide series of alloys where the free-cutting properties are obtained at the expense of the ductility and notch-toughness, it is possible in the free-cutting series of alloys containing zinc to obtain excellent machining properties with elongations of over 20%. The tensile strength of the alloys is dependent on the magnesium and zinc contents, and may range from 35 to 45 kg./mm.$^2$ in the soft-annealed condition, figures which may, of course, be greatly improved by cold-working if requisite.

This alloy is therefore now an established German free-cutting light alloy. For certain purposes the aluminium-copper-magnesium series with 3·5% Cu, 0·5% Mn, 0.5% Mg, and varying contents of lead bismuth and cadmium, either singly or in combination, is also important. The copper-containing series of German free-cutting light alloys go by the designation of WI 301. The silicon-containing series referred to earlier are also on the market under the serial designation WA 301.

Considerable attention has been paid to the corrosion behaviour of the different series of alloys. The Hydronalium DBA alloy is irreproachable in this respect : whilst the WI 301 and WA 301 have reasonably corrosion-resistant properties which allow them to be used for all but specially severe conditions. Fatigue-corrosion tests have shown the alloys to be quite capable of standing up to ordinary service.

The machining properties of the light alloys differ from those of steel and cast-iron varieties. The cutting tool does not suddenly lose its cutting ability, but a uniformly increasing wear is apparent on the cutting edge of the tool throughout the machining operations ; up to a certain point this wear is permissible, beyond this point it is definitely deleterious to the life and surface conditions of the tool. With light metals, high cutting speeds and feeds give the best results both from the point of view of the work and the tool. The diagrams in Fig. 1 show the influence of the cutting speed and of the top front rake angle on the cutting power in the cases of two different light alloys, and Fig. 2 shows some comparative curves for free-cutting light alloys, whilst Fig. 3a and Fig. 3b indicate comparison of three light alloys with a free-machining brass.

Lubrication of the free-machining light alloys does not require the use of special or new oils. Experience has shown that the light alloys are intermediate between the soft machine steels and the free-cutting brasses in their action on the lubricating properties of the cutting oils available. The same oils as are used with the brasses can therefore be employed with light alloys, but better results are actually obtained with the types of oil used for machining steel.

Meticulous cleaning of the machines from time to time is, of course, essential in order to remove any particles of aluminium alloys from the oil sump, and to ensure clean running of the machine.

## Aluminium Manufacture in Canada

THE Aluminium Co. of Canada, Ltd., recorded an increase of about 10% in its export sales last year, and of about 200% as compared with sales in 1932. The Arvida plant is operating at a high rate of capacity, and plans are in progress for further expansion. Four furnaces are now in operation, and more furnaces will be installed as soon as rotary converters have been put in place, changing the power supply from alternating to direct current for use in the furnaces. Last year's aluminium exports from Canada were valued at $11,100,000, as compared with $10,400,000 in 1935, and $3,900,000 in 1932. Aluminium ranked third in value last year among Canada's exports of base metals.

Recently, 100 tons of steel rails, each 120 ft. in length, were rolled by the Skinningrove Iron Co., Saltburn, Yorks., for service in the L.N.E.R. main line. These are believed to be the longest rails ever yet produced in one piece in any part of the world. The rolling was successfully accomplished, and the rails were laid in the down main line at Holme, near Peterborough. It is fully expected that by eliminating the number of rail joints the rails will greatly improve the running of trains by making smoother travel and lessening noise.

# Sulphur Recovery Processes

### Progress at Billingham.

INTERESTING details of the progress made in this country and abroad in the economic recovery of sulphur were given by Mr. M. P. Applebey, in a recent lecture on "The Recovery of Sulphur from Smelter Gases," before the Newcastle Section of the Society of Chemical Industry. The process developed at Billingham has now reached the commercial stage, being applicable to metallurgical gases of almost any $SO_2$ content, as well as capable of reducing the $SO_2$ content of such gases below the limit of concentration at which they are a nuisance. Its first stage alone can be employed to give concentrated sulphur dioxide for liquefaction and sale.

An experimental pilot plant has been in intermittent operation at the Billingham works of I.C.I. for several years, and is now in continuous production of about 20 tons of $SO_2$ gas per day. A reduction plant having an output of five to six tons of sulphur per day is also in production.

### Economic Significance.

Several factors had prompted research into the problem of dealing economically with waste sulphurous smelter gases. One of these was the economic value of the sulphur wasted in this way throughout the world, amounting to 2,000,000 tons per annum. There was also the desire for national self-sufficiency, and the necessity to abate the nuisance to health and to vegetation caused by the escape of acid gases.

Two successful recovery processes have been developed. One of these (the I.C.I. process) employs as a first stage a concentration process, followed by reduction of pure $SO_2$ to sulphur by means of coke. The other has been developed independently by Bolidens Gruvaktiebolag, of Sweden, and a company was formed last year, under the title of Sulphur Patents Ltd., for the joint exploitation and control of the two processes.

The Boliden process has no concentration stage, and depends upon reduction of the raw smelter gases with gases derived from coke. Thus, its application is best suited to metallurgical gases relatively strong in $SO_2$ and low in oxygen content. Some 20,000 to 25,000 tons of high-quality sulphur are produced annually at the Boliden Company's smelter at Rönnskär, Sweden, by this process. A copper smelter in Finland employs the I.C.I. process to produce 52 tons per day of liquid $SO_2$ from copper converter gases containing an average of 5% $SO_2$.

### Chemistry of the Processes.

Initial research at Billingham was directed towards evolving an efficient process for the concentration of the sulphur dioxide from the raw gases. This resolved itself into a search for a solution in which $SO_2$ could be absorbed in large quantities, and from which it could be readily regenerated. The choice eventually fell on a specially-prepared solution of basic aluminium sulphate. Mr. Applebey described the $SO_2$ absorption plant now in use at Billingham, and showed how such difficulties as the tendency to sulphate and thio-acid formation had been overcome.

### The Reduction Process.

Mr. Applebey also described the second stage (the reduction of $SO_2$ to sulphur) with reference to the Boliden process. This is divided into three stages, comprising the manufacture of reducing gas, the use of this for the catalytic reduction of the $SO_2$, and the cooling of the gases, with separation of the condensed sulphur by electrostatic precipitation.

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# Heat-resisting Materials

COMPARATIVE investigations on heat-resisting materials at high temperatures are given by Korber and Pomp in a recent communication.* Tests are carried out on the materials available as rods of 20 mm. dia. The chemical compositions of the materials are given in the accompanying table. The authors give the tensile properties of the materials at 20° C and also photographs of structure.

CHEMICAL COMPOSITION OF HEAT-RESISTING MATERIALS.

| Specimen No. | C. % | Si. % | Mn. % | P. % | S. % | Cr. % | Ni. % | W. % | Mo. % | Cu. % | Co. % | Ti % | V. % | Fe. % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0·43 | 3·23 | 0·33 | 0·021 | 0·002 | 8·43 | 0·08 | — | — | — | — | — | — | — |
| 2 | 0·40 | 4·23 | 0·33 | 0·022 | 0·004 | 3·42 | 0·09 | — | — | — | 1·76 | — | — | — |
| 3 | 0·47 | 1·49 | 0·80 | 0·016 | 0·004 | 14·78 | 12·94 | 2·16 | — | — | — | — | — | — |
| 4 | 0·46 | 0·52 | 1·31 | 0·025 | 0·006 | 12·71 | 12·86 | 9·65 | — | — | — | — | — | — |
| 5 | 0·95 | 1·63 | 0·74 | 0·011 | 0·039 | 15·14 | 12·80 | 2·45 | 0·08 | — | — | — | — | — |
| 6 | 1·31 | 0·44 | 0·42 | 0·022 | 0·007 | 13·98 | — | — | — | — | 1·96 | — | — | — |
| 7 | 0·94 | 0·50 | 0·18 | 0·010 | 0·030 | 16·62 | 0·18 | — | 0·59 | — | 2·28 | — | 0·35 | — |
| 8 | 0·11 | 0·56 | 0·62 | 0·011 | 0·025 | 17·72 | 8·48 | 1·03 | 0·20 | 0·23 | — | 0·22 | — | — |
| 9 | 0·67 | 2·05 | 5·16 | 0·022 | 0·012 | 15·89 | 0·35 | 5·27 | — | — | — | — | — | — |
| 10 | — | — | 1·78 | — | — | 15·10 | 60·30 | — | 7·18 | — | — | — | — | 15·4 |

Results of tests are given in tables and diagrams. Four different tests are carried out.

1. The yield points at 600° C. are determined and then tensile strength, elongation and contraction, being an interval of only about 3 mins. between the two parts of these experiments. Great changes have been found against the figures established at 20° C. and also the sequence of value of the different steels in reference to the four properties has changed very much and in quite different manner.

2. The tensile strength at temperatures ranging from 600° to 900° (tests lasting 20 minutes), decreases with increasing temperature continuously with exception of steels Nr 6 and 7, which have a maximum at 850° C., probably in consequence of internal transformations.

3. The impact hardnesses dependent on temperatures show a course very different from that of the tensile strengths in the 20 minutes test. The decrease of the latter between 600° and 900° is much more regular than that of the former. The steels 6, 7 and 8 show, after an initial decrease, a maximum hardness of between 800° and 850°.

4. Four of the specimens, steels 5, 7 and 8 and the alloy 10, are subjected to creep tests at 700° C, in which the extensive occurring under a load of 1 kg. per sq. mm. in an interval of 250 hours was measured. The best result gave steel 8 with a practical standstill of the creep after 50 hours. Steels 5 and 7 reached nearly the same result after about 200 hours, but alloy 10 had still a remarkable speed of elongation after 150 to 200 hours. The ratio of the total elongation after 240 hours was for the three groups :— 8 : (5 and 7) : 10 = 4 : 43 : 87.

* By Friedrich Korber and Anton Pomp. (Mitteilungen aus dein Kaiser-Wilhelm Institut fur Eisenforschung. Vol. XVIII, 1936. No. 18. Paper 314). Price RM. 1·0.

# Correspondence

## Heat-Treatment of Welds in Work of Special Character

The Editor, METALLURIA

Sir,—The Industrial Research Department of the South Metropolitan Gas Company undertook, in co-operation with Mr. H. Fergusson of Messrs. G. A. Harvey & Co. (London) Ltd., the even heating of circumferential welds, in order to relieve welding strains on large cylindrical pressure evaporating vessels or calandrias, which Messrs. Harvey had manufactured and which are believed to be the largest vessels of that type yet constructed.

Each vessel was 26 ft. 9 in. high, consisting of two shells each 10 ft. 4 in. high and a domed top and bottom, with an internal diameter of 11 ft. and designed for a working pressure of 250 lb. per sq. in. on the shell.

*Large cylindrical pressure evaporating vessel with temporary equipment for heat-treating to to relieve welding strains.*

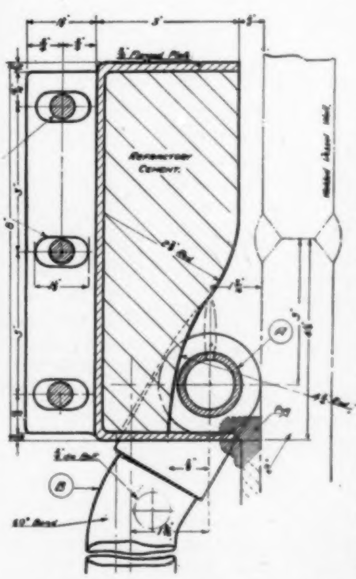


*Fig. 2.—(on right) showing sectional view of refractory lining.*

The bottom shell (calandria section), which was fabricated of $1\frac{5}{32}$ in. plate, had two tube plates each 1 in. thick in one piece between which were welded 1,792 tubes $1\frac{1}{4}$ in. bore. The test pressure for the calandria section was 375 lb. per sq. in. and that for the upper shell 285 lb. per sq. in.

All the main seams were X-rayed, altogether about 1,200 photographs being taken of the welding of the four vessels. Each vessel weighed 50 tons and had to be lifted 100 ft. from the ground to reach its destination at the client's works.

The work of heating the welds was one peculiarly suitable for gas and the design of the equipment was such that it was easy to move it from one weld to another, there being three welds per cylinder.

It will be appreciated that the calculation of the heat input required for one of the normal welds was not an easy matter and for those near the tube plates, connected as they were by welding with nearly 1,800 $1\frac{1}{4}$ in. diameter tubes, it was quite a complicated matter. However, the equipment was designed on some rough experiments carried out on a piece of the actual welded plate at the works of the South Metropolitan Gas Company, and proved in service satisfactory both to the fabricators of the vessels and the metallurgist of the underwriting Insurance Company, who witnessed the actual normalising operation.

The outside diameter was approximately 11 ft. 3 in. giving a length of circumferential weld of just over 35 ft., and it was decided to arrange the burners to give an equal heat input per foot of circumference of plate. Pressure

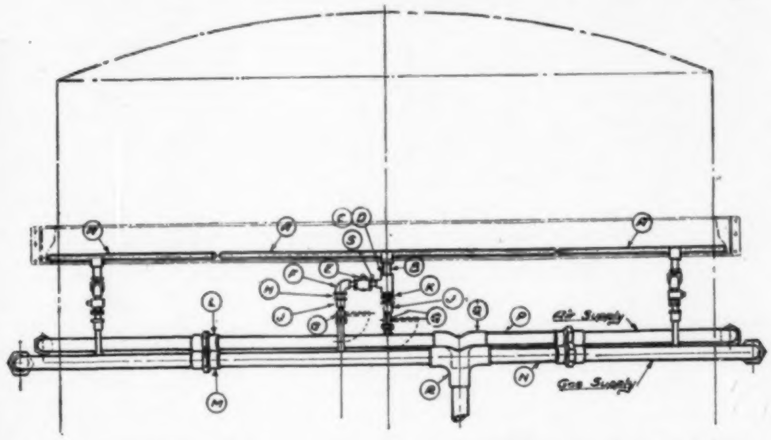



*Fig. 1.—General arrangement for heating the weld metal.*

air was available from a Roots-type blower in the shop and it was decided to use the air-blast-type of burner and to construct six sections, each of approximately 6 ft. length, of 1 in. diameter pipe, with $\frac{11}{64}$ in. diameter holes spaced at 1 in. centres, each of these six sections being independently fed with an air-gas mixture from two underslung circumferential pipes, one 2 in. diameter for air and the other $2\frac{1}{2}$ in. diameter for gas, these latter taking their supplies through armoured flexible hoses independent of their vertical position on the upright cylinder. (See Fig. 1.) For the sake of safety, each of the six 1 in. vertical gas leads to the mixing throats was provided with a back-pressure valve to obviate the possibility of air getting back into the gas service.

The flames from the six circumferential burners did not play directly on to the surface of the shell, but on to a monolithic refractory lining contained in a cylindrical housing of channel cross-section (see Fig. 2), made in six pieces, and so disposed as to shape and position relative to the burner that the surface immediately above the burner, and immediately opposite the weld, was maintained from almost the start in a state of incandescence and gave its heat directly and quickly by radiation to the steel surface, with, it is claimed, the minimum amount of scaling.

The burners proved very responsive to adjustment and it was found possible to secure uniformity of temperature all round the weld, as shown by the indications from

thermo-couples welded at intervals round the weld inside the shell, whose leads were taken trhough a convenient manhole to the indicating instruments on a table alongside.

D. Chandler.

## Heat-Treatment and the Component
### Their Treatment in Technical Articles

The Editor, Metallurgia

Sir,—If I ask for a little space to comment on the much appreciated contributions by Messrs. Plant and Chubb, it is mainly in an attempt to clarify further the general idea which prompted my original letter! Mr. Plant has himself amplified my remarks out of his own experience, and has suggested a remedy in the metallurgical education of engineers and users. If this is also to include the engineering education of chemists and metallurgists I am in hearty agreement.

But the main reason for my letter was not so much the larger issue as the more particular one of technical articles dealing with heat-treatment and the component! And in an appeal for more articles dealing with the problems connected with the component (as such) I am still of the opinion that this will go some way along the line of practical education.

Mr. Plant thinks that I appear to seek for a solution of my difficulties (which, like his, are mainly other people's) in the experience of others. Altering the word "solution" to "assistance towards a solution" this is quite as reasonable as accepting the laws of heat-treatment, equilibrium and constitutional diagrams, grain growth, etc., from technical lectures or text book, providing that I have the necessary equipment to understand and utilise such an education. It is parallel in nature to the discussions which usually follow the lectures of our technical societies!

Mr. Plant has, I am sure, so much of value to offer in this direction that he will not mind my attempt to emphasise the particular rather than the general.

Mr. Chubb went to some length to prove that there is a case for and against the testing of the component, and that it is necessary to decide each problem upon its merits. Now it is the merits of each problem that I am anxious to see expounded for the benefit of metallurgists and engineers. When I saw his example of the crown-wheel component I had great hopes that the first specific contribution to the series had commenced. But after producing his crown-wheel and tensile test-piece, Mr. Chubb left us with an unfinished last act to what appears to have been a highly controversial drama! In making a carburised test-piece to represent the working portion of a carburised component Mr. Chubb was showing the sense of realism I am anxious to see emphasised. We are left to assume however that he carried that realism a little farther by subjecting his test-piece to the same type of stress as that given to the tooth of the component is use.

The present writer has had, in the past, to assist in the endeavour to find test-pieces, static and working tests, which would give a routine indication of the durability of casehardened components.

Compression load to produce first crack in the case, on fully supported and partially supported test-pieces, gave valuable indications; as also did plain shear and bending tests. But, and this is important, the test-pieces bore at least a working relation in size, case depth, treatment and type of stress to the actual component.

In conclusion may I thank Mr. Plant and Mr. Chubb for their very interesting contributions.

Yours faithfully,

H. T.

April 23, 1937.

The Editor, Metallurgia

Sir,—If it is not too late to make a few comments on your correspondent's letter, I do not quite agree that it is also necessary for chemists and metallurgists to have an engineering education. After all, it is not for them to do other than produce the class of metal the engineer requires, though it is of paramount importance that the engineer shall know if the metal he proposes to use will stand up to the stresses and strains he requires, and further, a knowledge of the physical properties at least, of the metals will enable him to decide what metal to use within the scope of these stresses and also of dimensions. Some years ago, it fell to my lot to design a very large bridge for Denmark in international competition. While this design was not that chosen it had the merit of being classed among the first six. My work on that bridge was considerably assisted by a knowledge of the physical properties of steels, cast irons and wrought iron. This knowledge enabled me to include certain members in one metal where measurements and bulk had to be kept to a minimum, whilst I could use other metal in those places where stresses were less, or where extra bulk did not matter. But, assuming my design had been accepted, it would not have availed the steelmaker one little bit, when I placed my contract for the various sections of steel, had he an engineering knowledge. On the other hand, it would be essential for him to have his thorough metallurgical knowledge in order to produce steel to my specification.

Your correspondent stresses the fact that it is "the merits of each problem" which he is anxious to see expounded, and suggests that I might be able to offer something of value. This is probably true, but the types and classes of problems which one comes up against are so immense and varied that I feel it is always almost impossible to put any one forward which is going to act as a furtherance of general practical knowledge. I might, for instance, quote the instance of a draw-bar hook which fractured because the forging had not been done in the correct direction of the grain of the metal, or the malleable cast-iron casting which had been produced and was useless because the method of grain growth had not been considered in designing the component. Both these instances, and many more, are however of interest only to comparatively one or two people; they are not generalities, and I still feel that the "assistance towards a solution," accepting your correspondent's correction, is in a thorough study of those laws and theories which have, through research, been proved and which should be known by all those engaged in the design, manufacture and working of the metal under consideration.

Yours faithfully,

Walsall, C. Herbert Plant.

May 7, 1937.

# Catalogues and Other Publications

A booklet, entitled "The Twentieth Century Metal for the Twentieth Century Home," has been issued by the British Aluminium Co., Ltd., which describes some of the company's exhibits at the *Daily Mail* Ideal Home Exhibition, Scottish Section, Olympia.

Nickel which is refined at Clydach in South Wales comes from mines situated in the Sudbury district of Northern Ontario, owned by the International Nickel Co. of Canada, Ltd. In one of these mines, the Frood Mine, there is an ore body estimated to contain over 135 million tons. The whole process of the extraction of nickel, with special reference to the Mond process of nickel refining, is discussed in an interesting and informative manner in a booklet on the subject recently issued by the Bureau of Information on Nickel, the Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W. 1. The booklet deals with mining, concentration and smelting, refining, grinding, calcination, reduction and volatilisation, decomposition, medium pressure plant, subsidiary operations, and nickel sulphate manufacture.

## Orientation in Rolled Copper

WHEN a metal is subjected to a rolling operatioe, the individual grains or crystals tend to be broken up into smaller crystals, and accompanying thin breaking up is a motion of rotation such that each crystal tends to fall into a system of preferred orientation, which has a definite angular relation to the surface of the metal. The rolled crystals may orient themselves with respect to the axis of the rolls, or to the rolling direction, or both. The study of preferred orientation can be carried out by X-ray diffraction methods and is of great importance from two points of view. One is the possibility of better understanding the lattice forces within a metal, and the other, the changing physical properties of a metal when cold-worked. In respect to the latter, an investigation has been made by H. V. Anderson and C. H. Kehl,[1] to determine whether or not straight rolling of copper, as compared to reversed rolling for both heavy and light roll passes to the same total reduction, had any influence on the amount of preferred orientation produced on and below the original surface.

Four samples of rolled electrolytic copper were employed in the investigation. The chemical composition of the copper was 99·93 to 99·94% copper, 0·04% oxygen, arsenic and sulphur the remainder. The samples were subjected to light and heavy roll reductions by both straight rolling and reversed rolling, copper sheet being reduced from 0·168 in. to 0·050 in. by four and seven passes respectively, each pass giving a 10% reduction.

The preferred orientation in the various rolled samples was studied by two X-ray diffraction methods. One method consisted of obtaining a diffraction pattern of the specimen by surface reflection and the other method by transmission of the X-rays through thin sections of the specimen. With the first method, diffraction patterns were obtained by diffracting the incident beam from the surface layers of the specimens which were tilted approximately 15° to the horizontal, such that the incident beam struck the middle of the specimen and a diffraction pattern registered on a photographic film, placed 5 cm. from the point and perpendicular to the incident beam. One pattern of each sample was taken with the incident beam impinged along the direction of rolling and another with the beam impinged across the direction of rolling. An exposure of 72 hours was found necessary to give a satisfactory pattern without the use of intensifying screens. With the second method, transmission patterns were made of each sample, the X-ray beam passing through the specimen perpendicular to the surface, a photographic film being mounted 6 cm. from the specimen, perpendicular to the X-ray beam. The transmission specimens were prepared from the original samples by a careful etching with cold nitric acid to a thickness of 0·0098 to 0·0100 in., and an exposure of 48 hours was found to give satisfactory patterns.

Positive prints were made of all the diffraction patterns, and it was found that on all the patterns taken with the beam impinging along the direction of rolling, there was no indication of preferred orientation, and that only the patterns with the X-ray beam impinging across the direction of rolling showed a decided preferred orientation. The results obtained showed that the amount of preferred orientation produced on the surface of rolled copper is not influenced by the method of rolling, provided the total reduction is the same. The transmission patterns showed that below the original surface (at least below 0·0004 in.) a more random orientation is produced by reversed rolling than by straight rolling, while the severity of rolling to the same total reduction by both reversed rolling and straight rolling has no influence on the amount of surface or interior preferred orientation produced.

[1] *Metals and Alloys*, 1937, Vol. 8, pp. 73-76.

## Institute of British Foundrymen

The thirty-fourth Annual Conference of this Institute will be held at Derby from June 8–11, 1937, the arrangements for which are in the hands of the East Midlands Branch. The papers to be presented cover many aspects of modern foundry practice and of particular interest is a special session of papers on non-ferrous foundry subjects. The third "Edward Williams" lecture will be delivered by C. H. Desch, D.Sc., Ph.D., F.R.S., on the subject of "Factors in the Casting of Metals." The following papers will be presented at the technical sessions :—"Recommendations Concerning the Establishment of Costs in a Grey Iron Foundry," by the Costing Sub-Committee of the Technical Committee ; "Wear Tests on Ferrous Alloys," by O. W. Ellis ; "Additional Data on the Manufacture of Ingot Moulds," by R. Ballantine ; "Foundry and Laboratory Characteristics of Cupola Coke," by H. O'Neill, M.Met., D.Sc. and J. G. Pearce, M.Sc., F.Inst.P., M.I.E.E. ; "The Elimination of Gaseous Impurities in Aluminium," by Prof. Georges Chandren ; "Re-melting Aluminium in the Foundry," by Chief Engineer H. Rohrig ; "Notes on the Structure and Characteristics of Aluminium Alloys," by H. C. Hall, M.Met., F.I.C. ; "Trends in the Non-Ferrous Foundry," by L. B. Hunt, M.Sc., Ph.D. ; and "The Use of Nickel in Non-Ferrous Alloy Castings," by J. O. Hitchcock, B.Sc.

Derby is not wholly industrial, and the programme indicates that facilities are provided for enabling members and ladies to enjoy the delightful scenery in this district.

## International Association for Testing Materials visit Thos. Firth and John Brown's Works

ONE of the most interesting visits associated with the recent Congress of the International Association for Testing Materials was that to the works of Messrs. Thos. Firth and John Brown, Ltd., Sheffield, for which nearly 150 members and friends journeyed from London. On arrival at the works they were received by Dr. W. H. Hatfield, who conducted the party over many departments. Particular attention was directed, in the first place, to a specially designed ingot charging crane used in connection with a battery of Priest's furnaces. The construction of these furnaces and the operation of the crane are such that a large number of ingots can be charged at one time, as was demonstrated.

The large battery of electric melting furnaces, installed at these works, was shown in operation, a furnace being tapped and the metal cast into ingots. Passing through the electric steel-casting shop, the visitors were taken to the large new tool shop, where the small tools, for which this firm has a high reputation are manufactured. The fact that this tool shop is built on the site which was formerly occupied by the works in which Bessemer steel was first developed, added considerably to the interest of the visitors.

One of the most spectacular sights was the forging of a large boiler drum in the 6,000 ton press. From the small tools, amongst which were drills that were almost invisible, to boiler drums involving the use of ingots of approximately 200 tons in weight, gave the visitors some indication of the wide range of this firm's activities. From the 6,000 ton press the party visited the large machine shop, equipped for machining the largest forgings. Here again the wide range of work was evident.

The afternoon was allocated to the "Staybrite" sheet section of the works, previous to which the visitors were entertained to lunch at the Victoria Hotel. Mr. Allan J. Grant, J.P., managing director of Messrs. Thos. Firth and John Brown, Ltd., welcoming the visitors, apologised for the absence of the Rt. Hon. Lord Aberconway, C.B.E., Chairman of the Company, who had hoped to be present to receive them, but important business had called him away

from Sheffield. Mr. Grant expressed his pleasure that so many members of the Association had started at such an early hour to travel to the works. In the short time at their disposal it had only been possible to take them over a small part and it had not been possible to arrange for a visit to the Laboratories. He hoped, however, that the arrangements made were of interest. Prof. Dr. M. Roš, General Secretary of the International Association for Testing Materials, responded, expressing, in a very charming way, the pleasure of the members in having the opportunity to visit these works.

The subsequent visit to the "Staybrite" sheet department proved as interesting as the departments visited during the morning. In this department were seen the sheet rolling operations, the subsequent annealing of the sheets in a special type of gas-fired furnace, and the trimming, sorting and inspection of the sheets. Production of these sheets is organised on a semi-automatic plan, which operates very efficiently.

## Deterioration of Chromic-acid Baths used for Anodic Oxidation of Aluminium Alloys

In the commercial operation of chromic-acid baths for anodising aluminium alloys, the baths eventually fail to produce good films. When inferior films are formed the effectiveness of the solution may be temporarily restored by arbitrary additions of chromic acid, but a condition may be reached when further additions of chromic acid are without effect. Buzzard and Wilson have studied this aspect of anodising in order to determine the essential changes that occur in the continued operation of the chromic-acid baths and the conditions that must be controlled to maintain such baths in effective operation.

Hexavalent and trivalent chromium, aluminium, iron, copper, chlorides, and sulphates were found in a spent bath that had been used for anodising aluminium alloys. Experiments with freshly prepared chromic acid baths, to which were added, singly, amounts of the above substances slightly in excess of those found in the spent bath, indicated that failure of the bath was caused by a decrease of the content of hexavalent chromium or an increase in that of aluminium. Iron and sulphates, even when added in considerable excess over the amounts found in the spent bath, did not adversely affect the bath performance. Additions of chloride (which would not be present in normal bath operation) caused readily observable attack at both electrodes. On the basis of these preliminary tests, the investigation was confined to a study of the changes in the concentration of the principal constituents; namely, hexavalent chromium, trivalent chromium, and aluminium.

The rate at which the chromic-acid bath deteriorates when used was determined by anodising duralumin sheets. Iron cathodes were used and the chromic-acid solutions had concentrations of 3, 5 and 10% (0.3, 0.5 and 1.0 M). The anodising was conducted at 40° C., with a constant bath potential of 40 volts for periods of 7 hours. The anodes were renewed hourly, and a sample of the solution removed from the bath after each 25 hours of operation and analysed. The baths were operated until a heavy sludge formed.

The results of this investigation are summarised by the authors, who state that failure of anodising baths as a result of use is caused principally by the neutralisation of free chromic acid by aluminium. The true criterion of the working condition of the bath is the concentration of free chromic acid. *p*H measurements with a glass electrode furnish a convenient means for determining and controlling the condition of the bath, the useful life of which may be greatly prolonged by maintaining the solution at the required *p*H. The free chromic-acid content is maintained at the desired value by adding chromic acid to the bath in accordance with the *p*H values.

Experience has shown that maintenance of the bath at a constant *p*H ensures the obtaining of anodic oxide films that are very uniform in character.

By R. W. Buzzard and J. W. Wilson, *Jour. Research National Bureau of Standards,* Vol. 18, U.S. Depart. of Commerce.

## The Heterogeneity of Steel Ingots

(*Continued from page 22.*)

prior passage of hydrogen. From this it is concluded that the effect of nitrogen, previously reported, is essentially a physical effect, and is not due to the nitrogen forming compounds with the iron, as was suggested in the discussion of the previous Report.

Further experiments relating the influence of moisture are included, wherein it is shown that moisture tends to cause unsoundness in circumstances in which dry gas (either argon or air) causes no unsoundness.

The results of this further work are in line with those to be anticipated from the authors' previous communication on this subject.

### Ingot Moulds

Following joint meetings of the Heterogeneity of Steel Ingots and Open-hearth Committees an Ingot Moulds Sub-Committee was set up in 1934, and in Section VI of this (the parent) Report is given the first report of the Sub-Committee. The terms of reference are wide, and for the time being it is concentrating its whole attention upon the examination of all the factors which goven the life of ingot moulds in service.

Three principal paths of approach to the subject have been followed: One is an investigation of various failures of ingot moulds, and a detailed study of the influence of the composition and structure of the ingot mould iron upon mould failures, carried out by the British Cast Iron Research Association. Another is a statistical survey of the many factors which are known to affect the life of ingot moulds, carried out by making a careful and systematic study of the actual experience of a number of steelworks, determined by means of a questionnaire. The third consists of full-scale works experiments, designed to show the effect on mould-life of certain specific cupola charges, of the interval between casting and the removal of the mould from the sand, of subsequent annealing, of the interval between teeming the steel and stripping the ingot, and of high- and low-carbon steels.

The Sub-Committee is not yet in a position to lay down any definite scheme which will enable steel manufacturers to get the maximum life out of their moulds, but, nevertheless, the report yields many extremely useful indications which subsequent work is likely to confirm and amplify, and goes a long way towards clarifying a subject which, in the past, has been frequently obscured by the complexity and unreliability of the data hitherto collected by individual observers.

### Pyrometry

A further report of the Liquid Steel Temperature Sub-Committee is given in Section VII. This deals with work which has been carried out since the publication of the Sixth Ingot Report. The programme consists of a series of investigations, with the object of determining the temperature of molten steel directly in the furnace or the ladle. For this purpose the possibilities of the development of a suitable thermocouple are being explored, and several methods are at present under examination.

Dr. Fitterer's silicon-carbide/graphite combination is being investigated. Various "quick-immersion" methods are also being considered. In these (*a*) a platinum thermocouple, (*b*) a sighting tube for an optical pyrometer, and (*c*) metallic alloys in the form of wires, and having different melting points, are immersed in the liquid steel for a brief period of time. Details are given of laboratory tests which have been carried out, together with a trial of some of the apparatus on an open-hearth furnace.

# Reviews of Current Literature

## Journal of the Institute of Metals: Volume LIX (Proceedings). No. 2, 1936.

THOUGH the Institute of Metals has held meetings in many European countries, it was not until last autumn that this very international society of engineers and metallurgists first sampled French hospitality. From the record of the Institute's "Paris Autumn Meeting" contained in the newly-issued *Journal*, it would seem that the meeting was highly successful—technically, as well as socially.

The editor, however, deals but briefly with the dances, receptions and excursions that form a normal part of such a gathering in Paris, and makes up for his reticence in this direction by printing in full not only the 16 papers that were read at the business sessions—with the relative discussions and communications noted verbatim—but also the very informative Autumn Lecture by Professor P. A. Chevenard, on "The Scientific Organisation of Works." Hitherto, available only in French, the lecture is sure of a welcome in its English form by all who have anything to do with factory mangement or control.

The papers reproduced in the present volume cover such varied fields as soft soldering, production of aluminium reflectors, platinum group metals, forgeability of light alloys, and the creep of tin. The authors include distinguished French, German, Russian and Swiss investigators, as well as many British workers.

The general impression obtained by a careful perusal of the *Journal* is that the Institute responsible for its publication is singularly fortunate in possessing amongst its members so many famous metallurgists and engineers—men who are willing to come from all parts of the world (14 nations were represented at the Paris Conference) to throw their knowledge into a common pool, whence it crystallizes out in so useful a shape as the volume before us.

Edited by G. SHAW SCOTT, M.Sc., F.C.I.S. London: The Institute of Metals, 36, Victoria Street, Westminster, S.W. 1. £1 11s. 6d.

## The Preservation of Iron and Steel by Means of Paint

CONSIDERABLE research work on protective paints for iron and steel has been published, but it is, unfortunately, so scattered and often so inaccessible, that knowledge of it is often confined only to those research workers intimately concerned with it, and actual paint users, to whom the results would be of the utmost benefit, are left in ignorance. It is noteworthy, therefore, that the Research Association of British Paint, Colour, and Varnish Manufacturers have issued this, the first of a series of bulletins with the object of presenting a systematic classification and correlation of the published literature. The present issue reviews literature relating to anti-corrosive paint materials and, in addition, briefly describes the theories underlying their use, and the information given will assist in dispelling the considerable amount of existing misapprehension regarding anti-corrosive paints.

The authors discuss the modern theory of corrosion, but despite much research on the corrosion of metals the fundamentals of the problem are not understood, and a line of demarcation is still set up between chemical and electrolytic processes. The writer is inclined to the belief that the electrolytic theory covers all phenomena which take place when a metal is decomposed and loses its stability, and this view is apparently also held by the authors who confine their discussion to the electrolytic theory.

The protection conferred by a paint depends, broadly speaking, on the nature of the paint film and its capacity for adhesion to the surface painted; in a more detailed sense the protection depends upon the components of the paint—the pigment, medium, dryer—and not least, upon the method of manufacture, which is beyond the scope of analytical investigations. More study has been devoted to the effect of the pigment in the paint than to any other factor, probably because the pigment is easier than the medium to examine separately, and the authors give much useful information on the effect of the pigment in anti-corrosive paints and in primers. In addition, the effect of the medium and the pigment/medium ratio are fully discussed, while the general summary given at the end will be of great convenience to readers.

By L. A. JORDAN, D.Sc., A.R.C.Sc., F.I.C. and L. WHITBY, Ph.D., M.Sc., F.I.C., published by The Research Association of British Paint, Colour and Varnish Manufacturers, The Paint Research Station, Waldegrave Road, Teddington, Middlesex. Price, 2s. 6d. net; postage 2d.

## Symposium on Radiography and X-Ray Diffraction Methods

THE twelve technical papers comprising the symposium presented at four sessions of the 1936 annual meeting of the American Society for Testing Materials, together with extended discussions, are published in this book. The papers were prepared by outstanding authorities in the field, and form a symposium which is believed to be the first held in an English-speaking country on this subject. Six of the papers deal with radiography, covering principles, foundry applications, radiography in the welding shop, miscellaneous applications of radiography and fluoroscopy, radiographic specifications, and gamma-ray radiography, and its relation to X-ray radiography. An appendix to this latter paper provides instructions for radiography with radium. Authors of the papers in this section include: John T. Norton, Earnshaw Cook, J. C. Hodge, Herman E. Seeman, H. H. Lester, and Norman L. Mochel.

The six papers devoted to diffraction cover equipment and methods, constitution of alloys, chemical analysis, determination of particle size, applications to non-metallic materials, and to problems of cold work, preferred orientations, and recrystallisation. Authors in this section include Charles S. Barrett, Kent R. Van Horn, Wheeler P. Davey, John T. Norton, G. Harvey Cameron, and George L. Clark.

Copies in cloth binding can be obtained from A.S.T.M. Headquarters, 260, S. Broad Street, Philadelphia, at $4 each. Special prices are in effect on orders in quantity and for educational work.

## French Tinplate and Canning Industries

THE *Le Fer-Blanc et les Conserves en France*, Bulletin 5 of the International Tin Research and Development Council, has just appeared. This book, in French, was prepared in collaboration with l'Office Technique pour l'Utilisation de l'Acier, who were also instrumental in obtaining the photographs which occupy 48 pages, rather more space than the text. The photographs were taken specially for this book, and they convey a very clear idea of the great variety of processes and of products that the canning industry in France is concerned with. The text deals with canned foods from the point of view of wholesomeness, and is intended primarily for dietetians and doctors. Amongst the subjects dealt with are the general methods of preserving foods, the nutritive value of canned foods, and in particular of condensed milks, the food regulations of France as they apply to canned foods, and a brief account of tinplate manufacture.

A limited number of copies is available for free distribution in other countries besides France and application should be made direct to the International Tin Research and Development Council, at Manfield House, 378, Strand, London, W.C. 2.

## Iron-Vanadium Carbon Ternary System

A contribution to the knowledge of part of above system is made as a result of an investigation by Wever, Rose and Eggers. Two three-dimensional diagrams of the iron-vanadium-carbon system are used for discussing the principal possibilities of the spatial arrangements. The results of the literature concerning vanadium steels are compared and it is pointed out how far the opinions on the equilibria in the iron corner of the iron vanadium-carbon space diagram differ from one another. Therefore careful experiments have been carried out to check these contradictions and obtain an accurate position.

The iron-vanadium-carbon alloys are produced by melting ore of about 50 grammes with a proportion of 0·5, 1, 1·5, 2, and 5% vanadium and each time a different proportion of carbon between 0·01 and 2% under hydrogen as protecting gas. Ferro-vanadium of 79% V, Swedish pig-iron of 3·22% C and 0·19% Si and Armco-iron of 0·01% C are used as starting-materials. The test pieces are annealed 3 hours at 900 to 1,000° C. and then investigated principally by thermo-analytical means using curves of refrigeration or differences of temperatures. Cylinders of 15 mm. diameter and 1·5 mm. diameter and 7 mm. depth for the platinum/platinum-rhodium thermo-elements have been proved as suitable. The turnings obtained at the production of these test-pieces are used for the chemical analyses. The thermo elements are gauged according to the melting point of different metals and verified repeatedly. The structure of some test-pieces is investigated by microscopic means for confirming the results obtained by thermo-analytical methods.

The results of the author's investigations are presented in an extensive table of figures and five diagrams; they cannot be marked as very satisfactory. The reason for the differences between the diagrams of the different experimentators as well as the reason for the proportionally great scattering of the temperatures of transformation during the authors' experiments carried out with utmost carefulness, must be found in the peculiarity of the investigated ternary system: " On the one hand it is nearly impossible, owing to the hardly soluble vanadium-carbide, to obtain starting conditions equal for all tests, on the other hand the refrigeration is increased quite differently according as the quantity of the solved vanadium-carbide varies."

As a special result it is pointed out that in hypo-eutectoid steels pure vanadium austenite can exist at high temperature.

Franz Wever, Adolph Rose and Hans Eggers (Metteilungen aus dein Kaiser-Wilhelm-Institut fur Eisenforschung Vol. XVIII, 1936, No. 17, paper 313.) Price RM. 1·50.

## A.S.T.M. Methods of Chemical Analyses of Metals

FOR the first time the A.S.T.M. has issued a publication giving under one cover all of its methods of chemical analyses of the ferrous and non-ferrous metals. These include four methods for analysing ferrous metals, twelve for non-ferrous metals and alloys, three methods of quantitative spectrochemical analysis of non-ferrous metals. Included in the volume are the greatly amplified and modernised methods of chemical analysis of steel, cast iron, open-hearth iron and wrought iron. These new combined methods were developed to provide methods for the determination of important elements in plain and alloy steels and irons, and the new methods comprise an up-to-date treatise on this subject.

The publication of this book may be taken as a welcome sign of the times and an indication that users of materials are becoming more technically minded, and are likely to appreciate the compliment of having tried methods of analysis at their disposal. An interesting and useful addition are the methods for the sampling and analysis of several ferro-alloys.

The section on non-ferrous metals embraces methods for the analysis of bearing metals, brasses and bronzes, aluminium alloys, pig lead, slab zinc, nickel, electrical-resistance alloys and silver solders. The methods given have been compiled as standard procedures for use in referee analyses. They are not intended to preclude the use of other methods that give results within the permissible tolerances. These methods will find appreciation amongst many in the manufacturing and consuming industries, and metallurgists, in particular, will find the book of special interest and value.

Copies of this 250-page publication can be obtained from A.S.T.M. Headquarters, 260, Broad Street, Philadelphia, Penn. U.S.A., at $2.50 in cloth binding; $2 in heavy paper cover.

## Action of Metals on Lubricating Oils

The corrosion of copper, lead and tin and the influence of these metals upon the deterioration of commercial lubricating motor-oils has recently been studied. The deterioration was caused by heating samples of oils in glass basins for periods of two months at a temperature in the neighbourhood of that occurring in practice. Thin films of the various metals under test were produced on glass plates by evaporation under high vacuum, and these films were immersed in the oil during the test period. The films were so thin as to be transparent, and the effect of corrosion in thinning the films was to increase the transparency, and this property was conveniently used as a measure of the corrosion. It appears that the viscosity, surface tension and the acidity of the oils are not influenced by the metal present, but sludge formation is strongly stimulated in the presence of copper, while tin and lead have the opposite effect. Copper is strongly attacked, but tin and lead are protected by the film of reaction products. Oil stored in open cans for some months before the test was decidedly more corrosive than oil fresh from the sealed can.

These investigations by P. J. Haringhuizen and D. A. Was, of the University of Utrecht, are described in " Research on Thin Layers of Tin and Other Metals, III: The Interaction Between Metals and Lubricating Oils," published as Technical Publication No. 51 by the International Tin Research and Development Council, Manfield House, 378, Strand, London, W.C. 2, where copies may be obtained free of charge.

## The Kaiser-Wilhelm-Institute

A VERY complete description is given of the new buildings of the Kaiser Wilhelm-Institute for Iron Research. Created by the German Steelmakers' Association, the Institute began work at Aachen in 1918, but recently moved to new premises in Düsseldorf. The Institute is under the management of a director-scientist controlling independently the programme and methods of research work. Its task is purely scientific research into the realm of iron and steel technology. The new spacious buildings, which are described so fully in this communication, were visited by members of the Iron and Steel Institute when the annual meeting was held at Düsseldorf last year, in consequence of which this publication has more than ordinary interest for many in this country.

In addition to the buildings, each department together with its equipment is fully described. The most modern equipment and appliances for carrying out research work are installed and the Institute may be regarded as the most up-to-date of its kind in the world. The description covers 60 pages which are profusely illustrated.

By Friedrich Korber (Mitteilungen aus dien Kaiser-Wilheim-Institut fur Eisenforchung. Vol. XVIII, 1936, No. 19, paper 315). Price, RM, 6·0.

# Business Notes and News

## Complete Coking Plant for Turkey

As already announced a complete new iron and steel works is to be erected by the Turkish Government at Karabuk, about 130 miles north of Ankara, the capital of Turkey in Asia, or Anatolia as it is called. The contract for the work has been placed with Messrs. H. A. Brassert & Co. Ltd., of London. They have now given the order for the complete Coking Plant in connection with the new Works to Messrs. Simon-Carves Ltd., of Cheadle Heath, Stockport.

The contract is for 42 Simon-Carves "Underjet" Compound Coke Ovens of the Otto Twin-Flue type, with all necessary coke oven machinery, and a complete by-product plant, including crude benzol and rectification plant and electrostatic detarrers. Messrs. Simon-Carves' contract also comprises wagon tippler, coal handling plant, blending bunkers, reinforced concrete service bunker of 2,000 tons capacity, coke wharf, coke quenching station, and coke handling and screening plant.

## The L.N.E.R. Provides for Modern Motor Cars

In view of the great increase in the number of private motor cars sent by rail the L.N.E.R. is to provide special equipment in 190 covered carriage vehicles to enable them to be used more conveniently for the carriage of modern motor cars.

During the past few years the design of motor cars has developed enormously and the modern streamlined model is slung much lower than the older types of car. The carriage trucks were fitted for handling the older motor car body and the wheel bars or supports which hold the car in position in the truck have a range of height of from 9¼ in. to 21 in. above the floor. To accommodate many of the modern design cars it is necessary that these bars should be fixed to give a clearance from the floor as low as 5 in. and in view of the increased demands for this class of traffic the Company is to make the necessary alteration in its 190 carriage vehicles.

## London Passenger Transport Board (Railways)

The British Thomson-Houston Co., Ltd., has received an order from the London Passenger Transport Board for a large number of traction control equipments for use with tube rolling stock, the total value of which is in excess of £1,000,000. The equipments comprise control apparatus for driving and non-driving motor-cars and the wiring of control and auxiliary circuits on motor-cars and trailers.

The equipments will be of the PCM type, consisting of electro-pneumatically operated contactors and cam-operated contactor groups, arranged to give series-parallel control of two 140 H.P., 600 V, traction motors with automatic acceleration and two weak field running points in parallel, in addition to the usual series and parallel points. The whole of the contactors, together with their associated relays and resistances, will be arranged as a single unit designed for under-coach mounting.

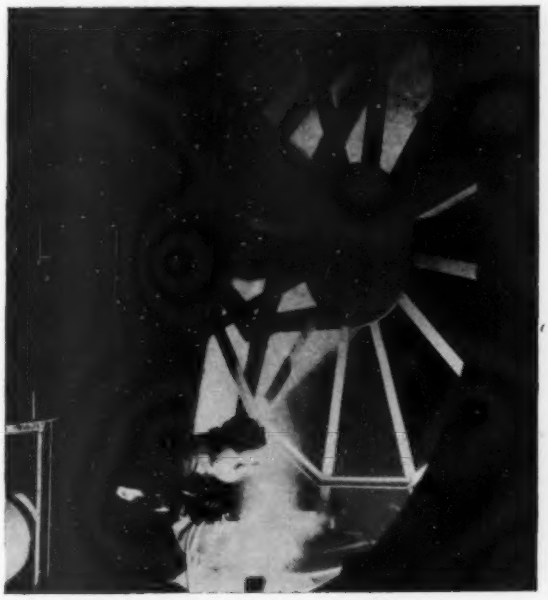
The motor control group utilises an unusual and unique arrangement of circuits, which allows the control unit to rotate in one direction while cutting out resistance during series acceleration, and to reverse its direction of operation so as to cut out the resistance sections in parallel while returning to its off position. This arrangement permits the provision of a large number of accelerating points in a simple controller, and allows a high rate of acceleration to be maintained without excessive current peaks.

These equipments have been designed so that they can be accommodated in the very limited height available under the coaches, thus dispensing with the equipment compartment which has hitherto been a feature of the standard tube trains: additional space will therefore be available for the accommodation of passengers.

These equipments will be mounted on new cars, which will be coupled together to form 4-car and 3-car train units, of which two units will be coupled together to form longer trains when required. The rate of acceleration and maximum speed possible with the new equipments will be considerably higher than is the case on existing standard trains.

## Foreign Scientists for International Geological Congress in Moscow

The great interest of geologists throughout the world in the International Geological Congress, which is to be opened in Moscow on July 20, may be judged by the ceaseless flow of applications received from foreign and Soviet scientists. Academician I. M. Gubkin, President of the Organising Committee of the Congress, has stated that the Commmittee has already received 360 applications from foreign scientists, 210 of whom have actually made arrangements for their arrival in Moscow. There will be a total of 1,200 delegates at the Congress, including 400 to 500 foreign scientists, many of them them world renowned geologists like Fourmarier (Belgium), Jacob Pruvost (France), Bruce (Canada), Howe, Morris, Dunbar and Hess (U.S.A.), Barbour and Gordon (England), Eskala (Finland), and Backlund (Sweden). As far as is known, the United States will be represented by 82 delegates, Great Britain by 17, France by 8, and South Africa by 10. Seventy papers to be read by foreign scientists at the Congress have already been received by the Organising Committee.



*By courtesy of the James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.*

*A "steel carpenter" at work in the manufacture of an 11 foot diameter water-cooled shell for an automatic gas producer at Willman Engineering Co., Cleveland, Ohio. The shell is of high tensile, corrosion-resisting low-alloy steel known as "Cor-ten."*

## Electric Furnace for Overseas

A 3½-ton electric furnace has recently been built by the machinery department of Edgar Allen and Co., Ltd., for the Electric Furnace Co., Ltd., London. This furnace is for overseas, and will be installed for the making of steel castings as well as ingots. The construction is largely standard, but the following points are worthy of note.

There have been incorporated balanced electrode gear, remote operated tightening gear for the electrode holders (by this means it is not necessary for the man to stand on the furnace roof for the changing of electrodes), special cast steel-stiffeners around the top of the furnace shell and over the door openings, radial and horizontal adjustment of the electrode arms being provided to enable the electrode pitch circle to be changed.

The electrical gear consists of a 1200 kVA transformer, having variable high reactance for arc furnace work, with several low tension voltages, the desired voltage being obtained by means of a motor-operated tap-change switch. The high-tension switch controlling the transformer is of standard type, complete with the necessary push buttons for operating the tap-change switch mentioned above. High-speed automatic electrode regulators are also provided.

The furnace is designed for melting a normal charge of 3½ tons in approximately 2½ hours. To this, of course, must be added the time for refining, etc.

## British Columbia Copper for Japan

The entire production of copper concentrate to be turned out shortly by the Granby Consolidated Mining, Smelting and Power Company, Ltd., at their British Columbia mines will, we understand, be supplied to the Japanese firms of Mitsui and Co. Ltd., and Mitsubishi Shoji Kaisha, Ltd. The contract runs for three years and provides for the supply of 4,000 tons of concentrate each month to be loaded at Vancouver on vessels provided by the Japanese firms named. The same firms are understood to be interested in nickel-copper concentrates from the British Columbia nickel mine.

Work is progressing rapidly at the Granby plants in the Similkameen in preparation for the reopening of the Copper Mountain mine and the resumption of operations of the 3,000-ton concentrator at Allenby. It is expected that milling will be started by the end of this month. The first unit of the 15,000 h.p. power house at Princeton is now working, and the transmission line to the mill has been completed. The line to the mine will be finished shortly.

## Furnace Works Extensions

Considerable extensions have recently made been to the works of Metalectric Furnaces Ltd., Smethwick, which are now fully occupied in the manufacture of a wide range of melting and heat-treatment furnaces. Particular interest is being shown in the melting furnaces manufactured by this firm, and among recent orders is a 15-ton steel melting furnace, also two 5-ton furnaces for special irons.

This firm has recently acquired control of the "Russ" patents in Great Britain, which are incorporated in the design of furnaces suitable for the melting and heat-treatment of light alloys; these furnaces embody the experience of the "Russ" organisation in Germany. In addition, the firm has secured licence and control in Great Britain for the Tagliaferri melting furnaces for iron and steel. Over 120 furnaces of this type have been installed with a total melting capacity of 700 tons and a rating of 250,000 kw.

With the extensions these works are of an exclusive character, incorporating ferrous and non-ferrous foundries, pattern, machine, steel fabrication and erection shops, which are fully equipped and adequately staffed. In addition the firm has a large staff of technical engineers and skilled metallurgists to advise on any particular heat-treatment or melting problem.

## Tinplate Output Restrictions Removed

In February, it will be remembered, as a result of increased demand for tinplate, the quota was raised from 70 to 75 per cent. Now the South Wales Tinplate Pool Committee has decided to remove the restriction on output of tinplate based on allocated capacity. This is the first time since 1932 and means that tinplate works may now operate up to their full capacity.

## Plans for Developing Brazilian Iron Ore

Considerable interest is attached to suggestions made for the development of Brazilian iron ore; the deposits are believed to be among the largest in the world. The development of the mines, which are situated mainly in the State of Minas Geraes, is greatly handicapped by poor transport facilities. A French concern controls a large part of the iron ore mining industry and steel production, and is building new blast-furnaces with an annual capacity of 150,000 tons.

Suggestions were made many years ago to the Brazilian Government for the reorganisation of the iron ore mining industry. In 1917 a British compnay, the Itabira Iron Ore Co., was formed, owning mines in Minas Geraes claimed to contain about 500 million tons of hæmatite ore. This Company submitted plans to the Brazilian Government for the formation of a new concession, but no decision was reached. In 1935, new proposals were put forward, which provided for the building of a railway line and shipping facilities in Santa Cruz. These proposals have now come before the Brazilian Parliament and, despite the controversy which has arisen as a result, there is a possibility that the plans may receive the sanction of Parliament.

## Iron and Steel Production in South Wales

The production of iron and steel is making remarkable progress in South Wales and recent figures show the trade reaching new high levels. In the first quarter of this year, for instance, official returns show the output of steel to be 76,200 tons more than the first quarter of last year and 194,500 tons more than in the corresponding period of 1935. With a continuance of this progress it is expected that the output for the half-year will be the largest of any district in the United Kingdom.

## Achema Annual, 1937

This profusely illustrated book which appears in the middle of May, has 388 pages. It will review with practically no omission the many products for scientific and industrial purposes of the German chemical apparatus and plant building industry as these products will be shown at the Achema VIII Chemical Engineering Exhibition. As is generally known, this Exhibition will be held from July 2 to 11 at Frankfort-on-Main on the occasion of the National Convention of German Chemists. This Annual prepares the visitor for what he will see at this Chemical Engineering Exhibition. Such a well planned preparation is a vital necessity. The multitude and variety of the apparatus, plant equipment, machines and accessories exhibited in seven halls with about 175,000 sq. ft. floor space make a careful study and systematic preparation. practically indispensable if one really wants to make the most of one's stay at Frankfort-on-Main. This Annual is supplied free of charge to those who have registered their visit to the Achema VIII in advance. Only three international reply coupons need be sent to cover postage. Prospective visitors to the Achema VIII may now register in advance at the Dechema German Society for Chemical Engineering, 103a, Potsdamerstrasse, Berlin W. 35.

# Some Recent Contracts

The L.N.E.R. have just placed orders with various firms in the West Riding of Yorkshire, Lancashire and Somerset for 57,900 yards of cloth, 152,500 yards of serge and 325,000 yards of blue jean. This amounts to 342 miles of material, a distance slightly greater than that from London to Berwick-on-Tweed. The material is required for uniforms, overalls, etc.

The Wellman Smith Owen Engineering Corporation, Ltd., has been awarded a contract by the Cleveland Bridge and Engineering Co., Ltd., Darlington, for the supply of two bridge erection cranes, to be employed in the erection of the cantilever bridge to be built over the Hooghly River, between Howrah and Calcutta. Each crane will be fitted with two jibs, each capable of dealing with 60-ton loads. Auxiliary lifts for loads up to 20 tons are also provided for. The design of these cranes calls for the introduction of many interesting and novel features, and involve the supply of considerably more than 1,000 tons of machinery.

A contract for the supply of 100 locomotive axle-boxes has been received by the North British Locomotive Co., Ltd., Glasgow, from the Bombay, Baroda and Central India Railway Administration. The North British Locomotive Co. have also received an order for six locomotive boilers for the Siamese State Railway.

The Admiralty announces that it has decided to entrust construction of the undermentioned submarines of the 1936 programme to the following companies: H.M.S. *Triumph* to Vickers-Armstrongs, Ltd., Barrow-in-Furness; H.M.S. *Trident* to Cammell Laird and Co., Ltd., Birkenhead; and H.M.S. *Tribune* to Scott's Shipbuilding and Engineering Co., Ltd., Greenock. The river gunboat, H.M.S. *Scorpion*, will be built by J. Samuel White and Co., Ltd., Cowes, Isle of Wight.

The Caledon Shipbuilding and Engineering Co., Ltd., of Dundee, recently received an order from the Adelaide Steamship Co., Ltd., for a vessel of 3,500 tons, deadweight. This brings the number of vessels which the Caledon Co. is building for the Australian company to three. The machinery for the new vessel will be supplied by James G. Kincaid and Co., Ltd., of Greenock.

# Aircraft Structures and Materials

IN the twenty-second annual report of the National Advisory Committee for Aeronautics the results of investigations are given by the Sub-Committee on metals used in aircraft. In connection with investigations on the weathering of light-alloy structural sheet material, a series of tests which have been in progress at Washington, D.C.; Hampton Roads, Va.; Coco Solo, C.Z.; will shortly be completed after four years' continuous exposure of specimens to the weather. Although the initial test programme was arranged to cover five years, it is felt that they will have essentially fulfilled the purpose in the somewhat shorter time. The results definitely establish the markedly superior properties, with respect to corrosion-resistance, of the aluminium alloys containing magnesium as the alloying constituent over similar alloys containing copper as an essential alloying constituent. The tests have also given valuable information with respect to the coating processes which are dependable for use on aluminium-alloy structures which must withstand severe atmospheric conditions. The Alclad materials have proved very resistant under all conditions imposed upon them. These various classes of alloys can be depended upon to give eminent satisfaction over a stipulated minimum five-year service life of an aircraft.

In the summarising report, detailed information is given on the microstructural aspect of the corrosion of aluminium-alloy sheet and its relation to the lowering of the mechanical properties of the material. The correlation of the results of laboratory tests by the salt-spray method on a large number of specimens with the results obtained with similar materials exposed continuously serves as a basis for a practical evaluation of this method of testing, which is extensively used in specifications in the aircraft industry.

A programme to supplement these tests has been authorised and tests have been planned to give information on specific items of general importance in aircraft construction, such as spotwelding, riveting, as well as newly developed protective coatings.

### Protective Surface-Treatment of Magnesium Alloys

An electrolytic method has been developed for the surface-treatnemt of magnesium alloys which is analogous to the anodic process used for aluminium alloys. The process is being applied on a commercial scale at the Naval Aircraft Factory. This method for treating the surface of magnesium has proved superior, in a number of ways, to other processes for the same purpose, although it is not so simple in application as the corresponding anodic process for aluminium alloys, since the various types of magnesium alloys differ somewhat in their response to the treatment. Work is being continued for defining the proper conditions for each type of this class of alloy. Weather-exposure tests are in progress to supplement extensive laboratory tests by the salt-spray method to determine the relative merits of magnesium alloys treated by this and other methods, the treated specimens being coated with various kinds of priming and finishing coats recommended for magnesium.

### Structural Changes in Aircraft Metals Occurring as a Result of Service Stressing

It is well established that marked structural changes which are conducive to short service life occur in certain soft alloys as a result of the stress conditions which occur in service. An investigation has been started to show whether or not highly stressed aircraft metals, particularly propeller materials, may be subject to similar detrimental structural changes. The work has been confined to the aluminium propeller alloy, 25 S, with special emphasis on its behaviour under fatigue stress.

X-ray study by reflection methods at an angle of grazing incidence of the same spot on the surface of a fatigue-test specimen as it is fatigue-stressed at successively higher maximum fibre stresses from 12,000 lb. to 18,000 lb. per sq. in. has shown no significant changes in the reflection pattern.

A testing programme on the aluminium-alloy propeller material is now under way to show to what extent, if any, fatigue-stressing may affect the other machanical properties of the material. Special attention being given to the possible effect of fatigue-stressing on the impact resistance of the material. Information on this point is urgently needed.

Certain microstructural features, "slip-plane precipitation" and "veining," observed in 25 S which have aroused some suspicion as to its origin and significance have been found in individual grains throughout most of the length of practically all the blades studied. These features are evidently not characteristic of areas of maximum service stresses. Their appearance is associated with heat-treatment procedure. Results have been obtained which indicate that this condition can be more readily revealed in material which has been fatigue stressed than in the same material initially. However, the practical significance of this fact, if it has any, is not apparent as yet.

Results of a systematic study of the rate of "growth" of the heat-treated 25 S alloy indicate that growth in the material continues long after the maximum hardness of the alloy has been attained, which fact may have some significance with respect to internal stresses in the finished material as it goes into service.

### Aircraft Metals at Sub-zero Temperatures

A programme of tests has been carried on during the year for obtaining information requested by the Bureau of Aeronautics on the common mechanical properties of aircraft structural metals at subnormal temperatures, approximating those which occur in service. These properties were determined at a series of temperatures ranging from room temperature to $-78 \cdot 5°$ C. ($-109°$ F.). Information has been obtained on stainless steel, 18–8, and on the same material "stabilised" by means of titanium and by columbium; on representative aluminium alloys, cast and wrought; magnesium alloys, cast and wrought; chromium-nickel alloy, "Inconel" (Cr 15%, Fe 6%, Ni 79%); chromium-nickel-molybdenum steel (C 0·47%, Cr 1·04%, Ni 1·80%, Mo 0·22%); high-chromium steel (C 0·11%, Cr 16·3%, Ni 1·72%).

Practically all the materials have shown an increase in the yield strength and ultimate strength at the lowered temperature with no change in the modulus of elasticity and only slight or insignificant decrease in the ductility. A very reassuring result of the tests to date on many of the materials is the fact that the impact resistance of notched specimens determined at the low temperature, $-78 \cdot 5°$ C., is not materially different from the value obtained on the same material at room temperature. For a few of the materials, however, some decrease in this property was noted. A report summarising the work is in preparation as a Research Paper of the National Bureau of Standards.

# Personal

As the Chairman of Edgar Allen and Co. (South Africa), Ltd., Johannesburg, Mr. C. F. Lucas, is shortly coming to England on leave, Mr. G. N. Nicholson, a southern representative of the firm, has already left England to act as a salesman during the period of his absence. Mr. Nicholson expects to return to this country about the end of the year.

Messrs. David Brown & Sons (Hudd.) Ltd., Huddersfield, have appointed Mr. F. M. Abbey as District Representative for the Eastern Counties. He has been in their employ at Huddersfield for nearly twenty years in various technical capacities and will be able to advise customers on all design and service matters in connection with gear drives. He has taken up residence at 24, Henley Road, Ipswich (Telephone: Ipswich 3435).

# MARKET PRICES

## ALUMINIUM.

| | | | | |
|---|---|---|---|---|
| 98/99% Purity | | £100 | 0 | 0 |

## ANTIMONY.

| | | | | |
|---|---|---|---|---|
| English | | £86 | 0 | 0 |
| Chinese | | 71 | 0 | 0 |
| Crude | | 37 | 0 | 0 |

## BRASS.

| | | | | |
|---|---|---|---|---|
| Solid Drawn Tubes | lb. | 0 | 1 | 0¾ |
| Brazed Tubes | ,, | 0 | 1 | 2¼ |
| Rods Drawn | ,, | 0 | | 11 |
| Wire | ,, | 0 | 0 | 10¼ |
| *Extruded Brass Bars | ,, | 0 | 0 | 7 |

## COPPER.

| | | | | |
|---|---|---|---|---|
| Standard Cash | | £60 | 15 | 0 |
| Electrolytic | | 63 | 10 | 0 |
| Best Selected | | 63 | 5 | 0 |
| Tough | | 62 | 15 | 0 |
| Sheets | | 94 | 0 | 0 |
| Wire Bars | | 64 | 10 | 0 |
| Ingot Bars | | 64 | 10 | 0 |
| Solid Drawn Tubes | lb. | 0 | 1 | 2¼ |
| Brazed Tubes | ,, | 0 | 1 | 2¾ |

## FERRO ALLOYS.

| | | | | |
|---|---|---|---|---|
| ‡Tungsten Metal Powder | lb. | £0 | 5 | 1½ |
| ‡Ferro Tungsten | ,, | 0 | 5 | 0 |
| Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up. | | | | |
| NOMINAL 2–4% Carbon, scale 11/- per unit | ton | 30 | 10 | 0 |
| NOMINAL 4–6% Carbon, scale 7/- per unit | ,, | 22 | 7 | 6 |
| NOMINAL 6–8% Carbon, scale 7/- per unit | ,, | 21 | 12 | 0 |
| NOMINAL 8–10% Carbon, scale 7/- per unit | ,, | 21 | 12 | 0 |
| §Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/- per unit | ,, | 33 | 0 | 0 |
| Guar. max. 1% Carbon, scale 12/6 per unit | ,, | 36 | 0 | 0 |
| §Guar. max. 0.5% Carbon, scale 12/6 per unit | ,, | 37 | 10 | 0 |
| ‡Manganese Metal 97–98% Mn | lb. | 0 | 1 | 3 |
| ‡Metallic Chromium | ,, | 0 | 2 | 5 |
| §Ferro-Vanadium 25–50% | ,, | 0 | 12 | 8 |
| §Spiegel, 18–20% | ton | 8 | 5 | 0 |
| Ferro Silicon— | | | | |
| Basis 10%, scale 3/- per unit nominal | ton | 10 | 0 | 0 |
| 20/30% basis 25%, scale 3/6 per unit | ,, | 13 | 10 | 0 |
| 45/50% basis 45%, scale 5/- per unit | ,, | 11 | 15 | 0 |
| 70/80% basis 75%, scale 7/- per unit | ,, | 16 | 15 | 0 |
| 90/95% basis 90%, scale 10/- per unit | ,, | 28 | 17 | 6 |
| §Silico Manganese 65/75% Mn., basis 65% Mn. | ,, | 15 | 15 | 0 |
| §Ferro - Carbon Titanium, 15/18% Ti | lb. | 0 | 0 | 4½ |
| Ferro Phosphorus, 20–25% | ton | 22 | 0 | 0 |
| §Ferro-Molybdenum, Molyte | lb. | 0 | 4 | 9 |
| §Calcium Molybdate | ,, | 0 | 4 | 5 |

## FUELS.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Foundry Coke— | | | | | | | |
| S. Wales | £1 | 12 | 6 to | 1 | 17 | 6 |
| Scotland | — | | | — | | |
| Durham | — | | | 1 | 8 | 0 |
| Furnace Coke— | | | | | | |
| Scotland | — | | | 1 | 8 | 0 |
| S. Wales | — | | | 1 | 7 | 6 |
| Durham | — | | | 1 | 12 | 6 |

## GUN METAL.

| | | | | |
|---|---|---|---|---|
| *Admiralty Gunmetal Ingots (88 : 10 : 2) | | £85 | 0 | 0 |
| *Commercial Ingots | | 68 | 0 | 0 |
| *Gunmetal Bars, Tank brand, 1 in. dia. and upwards | lb. | 0 | 1 | 1 |
| *Cored Bars | ,, | 0 | 1 | 3 |

## MANUFACTURED IRON.

| | | | |
|---|---|---|---|
| Scotland— | | | |
| Crown Bars, | £11 | 17 | 0 |
| N.E. Coast— | | | |
| Rivets | 11 | 15 | 0 |
| Best Bars | 12 | 10 | 0 |
| Common Bars | 10 | 15 | 0 |
| Lancashire— | | | |
| Crown Bars | 11 | 17 | 6 |
| Hoops | 12 | 15 | 0 |
| Midlands— | | | |
| Crown Bars | 11 | 17 | 6 |
| Marked Bars | 14 | 7 | 6 |
| Unmarked Bars | — | | |
| Nut and Bolt Bars | 10 | 15 | 0 |
| Gas Strip | 12 | 15 | 0 |
| S. Yorks.— | | | |
| Best Bars | 11 | 17 | 0 |
| Hoops | 12 | 15 | 0 |

## PHOSPHOR BRONZE.

| | | | | |
|---|---|---|---|---|
| *Bars, "Tank" brand, 1 in. dia. and upwards—Solid | lb. | £0 | 1 | 1 |
| *Cored Bars | ,, | 0 | 1 | 3 |
| †Strip | ,, | 0 | 1 | 1¼ |
| †Sheet to 10 W.G. | ,, | 0 | 1 | 1¾ |
| †Wire | ,, | 0 | 1 | 3¼ |
| †Rods | ,, | 0 | 1 | 4 |
| †Tubes | ,, | 0 | 1 | 6½ |
| †Castings | ,, | 0 | 1 | 3½ |

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

## PIG IRON.

| | | | |
|---|---|---|---|
| Scotland— | | | |
| Hæmatite M/Nos. | £6 | 3 | 0 |
| Foundry No. 1 | 5 | 15 | 6 |
| ,, No. 3 | 5 | 13 | 0 |
| N.E. Coast— | | | |
| Hæmatite No. 1 | 6 | 3 | 0 |
| Foundry No. 1 | 4 | 3 | 6 |
| ,, No. 3 | 4 | 1 | 0 |
| ,, No. 4 | 4 | 0 | 0 |
| Silicon Iron | — | | |
| Forge | 4 | 0 | 0 |
| Midlands— | | | |
| N. Staffs. Forge No. 4 | 4 | 3 | 0 |
| ,, Foundry No. 3 | 4 | 6 | 0 |
| Northants— | | | |
| Foundry No. 1 | 4 | 6 | 6 |
| Forge No. 4 | 4 | 0 | 6 |
| Foundry No. 3 | 4 | 3 | 6 |
| Derbyshire Forge | 4 | 3 | 0 |
| ,, Foundry No. 1 | 4 | 9 | 0 |
| ,, Foundry No. 3 | 4 | 6 | 0 |
| West Coast Hæmatite | 6 | 8 | 6 |
| East ,, | — | | |

## SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.
Per English ton ......... Kr.180
Billets, single welded, over 0·45 Carbon.
Per metric ton ......... Kr.315-385
Per English ton .. £16 5 0/£19 17 6
Wire Rods, over 0·45 Carbon.
Per metric ton ......... Kr.365-385
Per English ton .. £18 17 6/£19 17 6
Rolled Martin Iron, basis price.
Per metric ton ......... Kr.315-330
Per English ton .... £16 5 0/£17 0 0
Rolled charcoal iron, finished bars, basis price.
Per metric ton ......... Kr.360
Per English ton ......... £18 12 6
f.o.b. Gothenburg.

## SCRAP METAL.

| | | | |
|---|---|---|---|
| Copper, Clean | £48 | 0 | 0 |
| ,, Braziery | 43 | 0 | 0 |
| ,, Wire | — | | |
| Brass | 31 | 0 | 0 |
| Gun Metal | 45 | 0 | 0 |
| Zinc | 15 | 0 | 0 |
| Aluminium Cuttings | 74 | 0 | 0 |
| Lead | 20 | 0 | 0 |
| Heavy Steel— | | | |
| S. Wales | 3 | 10 | 0 |
| Scotland | 3 | 6 | 0 |
| Cleveland | 3 | 7 | 0 |
| Cast Iron— | | | |
| Midlands | 3 | 5 | 0 |
| S. Wales | 3 | 10 | 0 |
| Cleveland | 4 | 2 | 6 |
| Steel Turnings— | | | |
| Cleveland | 2 | 12 | 6 |
| Midlands | 2 | 5 | 0 |
| Cast Iron Borings— | | | |
| Cleveland | — | | |
| Scotland | 2 | 2 | 6 |

## SPELTER.

| | | | |
|---|---|---|---|
| G.O.B. Official | — | | |
| Hard | £20 | 5 | 0 |
| English | 24 | 0 | 0 |
| India | 20 | 0 | 0 |
| Re-melted | 20 | 5 | 0 |

## STEEL.

| | | | |
|---|---|---|---|
| Ship, Bridge, and Tank Plates. | | | |
| Scotland | £11 | 10 | 0 |
| North-East Coast | 11 | 10 | 0 |
| Midlands | 11 | 10 | 0 |
| Boiler Plates (Land) Scotland | 12 | 0 | 0 |
| ,, ,, (Marine) ,, | — | | |
| ,, ,, (Land), N.E.Coast | 12 | 0 | 0 |
| ,, ,, (Marine) ,, | — | | |
| Angles, Scotland | 11 | 0 | 6 |
| ,, North-East Coast | 11 | 0 | 6 |
| ,, Midlands | 11 | 0 | 6 |
| Joists | 11 | 6 | 0 |
| Heavy Rails | 10 | 2 | 6 |
| Fishplates | 14 | 2 | 6 |
| Light Rails | 10 | 7 | 6 |
| Sheffield— | | | |
| Siemens Acid Billets | 11 | 15 | 0 |
| Hard Basic .. £6 17 6 to | 10 | 2 | 6 |
| Medium Basic, £6 12 6 and | 10 | 0 | 0 |
| Soft Basic | 8 | 15 | 0 |
| Hoops | 11 | 15 | 0 |
| Manchester | | | |
| Hoops | 11 | 5 | 0 |
| Scotland, Sheets 24 B.G. | 15 | 15 | 0 |

## HIGH-SPEED TOOL STEEL.

| | | | | |
|---|---|---|---|---|
| Finished Bars 14% Tungsten | lb. | £0 | 2 | 7 |
| Finished Bars 18% Tungsten | ,, | 0 | 3 | 6 |
| Extras : | | | | |
| Round and Squares, ½ in. to ¼ in. | ,, | 0 | 0 | 3 |
| Under ¼ in. to ⅛ in. | ,, | 0 | 1 | 0 |
| Round and Squares, 3 in. | ,, | 0 | 0 | 4 |
| Flats under 1 in. × ⅜ in. | ,, | 0 | 0 | 3 |
| ,, ,, ½ in. × ¼ in. | ,, | 0 | 1 | 0 |

## TIN.

| | | | |
|---|---|---|---|
| Standard Cash | £247 | 15 | 0 |
| English | £248 | 0 | 0 |
| Australian | — | | |
| Eastern | 246 | 5 | 0 |
| Tin Plates I.C. 20 × 14 box | 1 | 4 | 6 |

## ZINC.

| | | | |
|---|---|---|---|
| English Sheets | £37 | 0 | 0 |
| Rods | 31 | 0 | 0 |
| Battery Plates | — | | |
| Boiler Plates | — | | |

## LEAD.

| | | | |
|---|---|---|---|
| Soft Foreign | £23 | 10 | 0 |
| English | 25 | 10 | 0 |

* McKechnie Brothers, Ltd., May 13. † C. Clifford & Son, Ltd., May 13. ‡ Murex Limited, May 13.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices when about to place order.
§ Prices ex warehouse, May 13.

**METALLURGIA.** *Contents.* For MAY, 1937.

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We have received a request to supply the following copies of "Metallurgia":—

January, 1930 — February, 1930
November, 1932 — February, 1935
December, 1935
also Indexes to Volumes 1, 2 and 8.

We are unable to supply copies of these issues, and would appreciate any reader, who may have copies of these issues, sending them along to us, the cost of which would, of course, be refunded.

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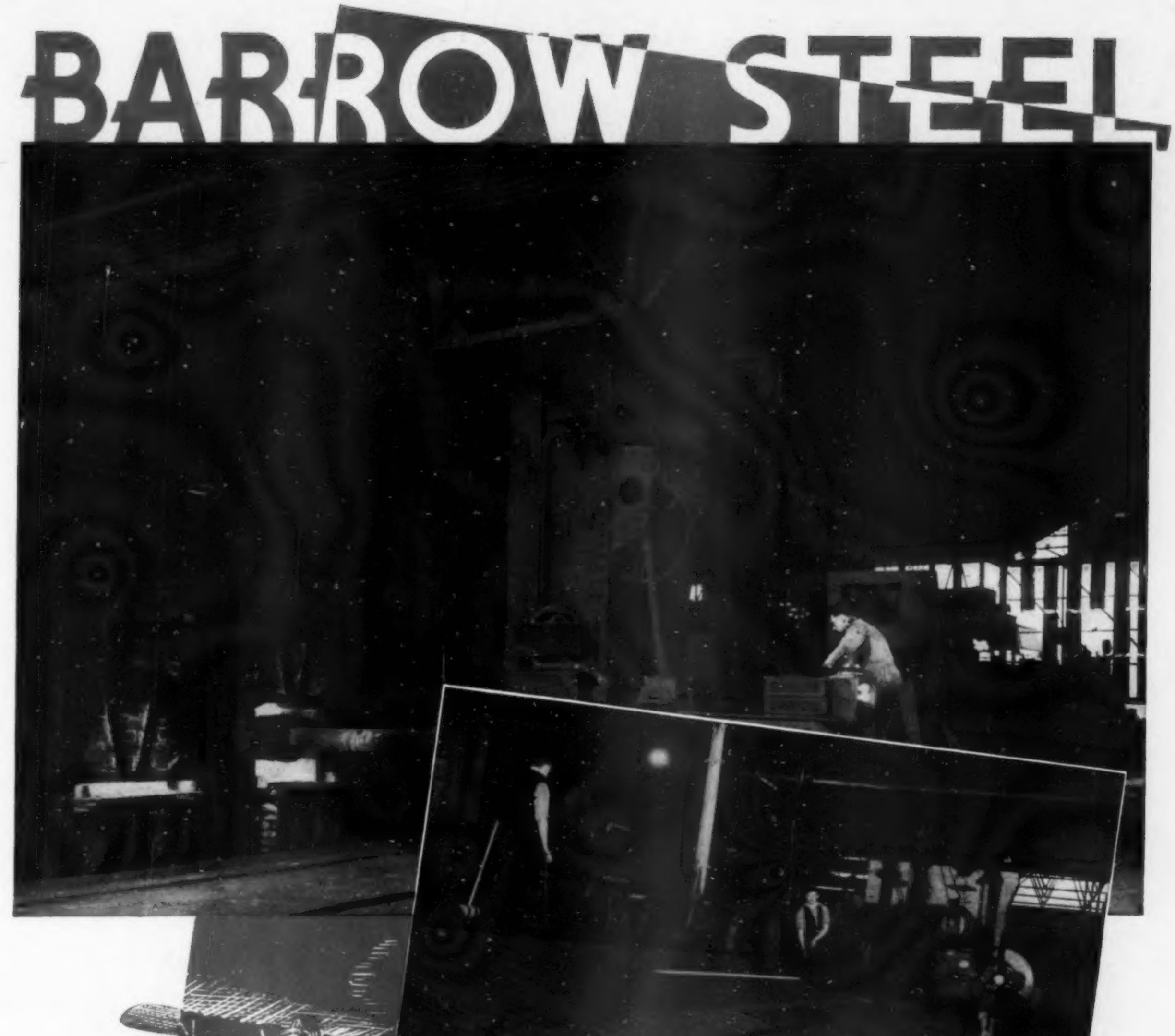


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